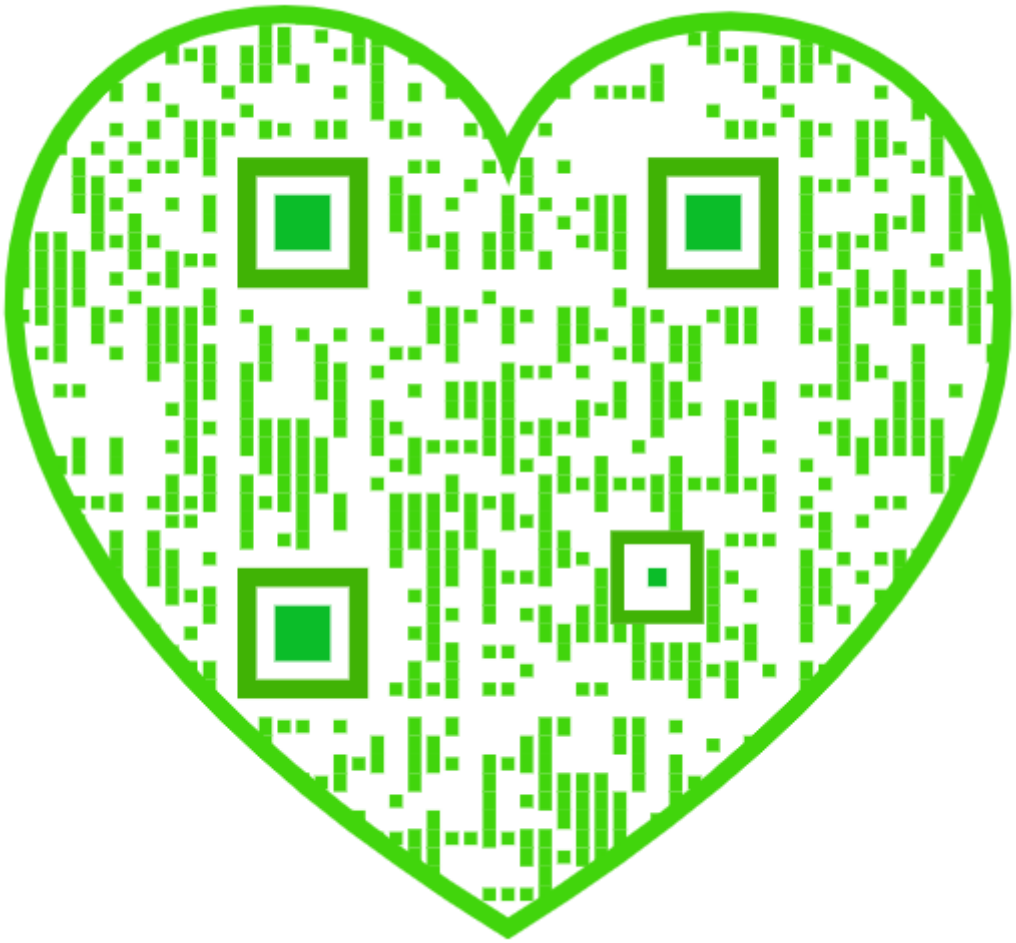

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IN WORKS OF

INTERMITTENT DOWNWARD FILTRATION,

Separately and in Combination with Surface Irrigation;

WITH NOTES ON THE PRACTICE AND RESULTS OF SEWAGE FARMING.

BY

J. BAILEY-DENTON,

Thirty-five years Principal Engineer to the General Land Drainage and Improvement Company.

Chevalier du Mérite Agricole (France).

1885.

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INTERMITTENT FILTRATION.

WORKS BY MR. BAILEY-DENTON, M. Inst. C.E.; F.G.S.

Honorary Member of the R.A.S.S. of Denmark, Sweden, and Hanover.

Land Drainage and Drainage Systems, 1854.
Underdrainage of Land; its progress and results, 1855. (Society of Arts Medal.)
Road-making, 1857; Prize Essay.
The effect of Underdrainage on Arterial Channels and Outfalls, 1858.
The Discharge from Underdrainage, 1863. (Telford Medal, Inst. C.E.)
The Farm Homesteads of England, 1864.
The importance of Shelter and Covering at Homesteads in certain Districts of Great Britain, 1865.
The Marshes of South Italy, 1865.
The Water Question, 1866.
Village Sanitary Economy.
The Agricultural Labourer, 1868.
Sanitary Works, 1869.
Sewage Farming, 1870.
Sewage the Fertilizer of Land, and Land the Purifier of Sewage, 1871.
Underdrainage and the steps to be taken to develop and maintain its effects, 1872.
Intermittent Downward Filtration and Irrigation, 1873.
Sanitary Science applied to Towns and Rural Districts, 1874.
Storage of Water, 1874.
Sanitary Engineering (a Series of Lectures given before the School of Military Engineering at Chatham), 1876.
Lectures on the Water Economy of Great Britain; on the Storage of Water; and on Land Drainage, given at the Royal Agricultural College, Cirencester.
Technical Teaching at Rural Elementary Schools, 1878.

Such of the above works as now remain in print can be obtained of Messrs. Spon, 125, Strand.

Also,

HANDBOOK OF HOUSE SANITATION,
FOR ALL PERSONS SEEKING A HEALTHY HOME.

By Eardley Bailey-Denton, C.E., B.A.,
22, Whitehall Place, London.

PREFACE TO SECOND EDITION.

INTERMITTENT FILTRATION having been somewhat prominently referred to in terms of approval by the Royal Commission on Metropolitan Sewage Discharge, and the treatise entitled "Ten Years' Experience in Works of Intermittent Downward Filtration," published in 1880, from which sundry quotations have been made, being out of print, its author has determined to issue a second edition through the same publishers. In order that the importance of the subject and its bearing on the future treatment of sewage may be better appreciated than it could be through the work itself only, the following portions of the Commissioners' Report are here reproduced:—

"We have also alluded to a novel system of sewage treatment which was first proposed in the Rivers Pollution Commissioners' Report of 1870 on the Mersey and Ribble basins. This system consisted simply in making the filtration through porous land the *principal* instead of an incidental process of sewage treatment.

"In the course of investigations on various modes of sewage disposal it seems to have attracted the attention of Dr. Frankland (to whom the new process is ascribed) that in some cases where such filtration naturally occurred the result was to purify the sewage in a remarkable degree—in fact, that what were known as pure streams were often only derived from sewage filtered in this manner. Hence it occurred to him to try whether a plan might not be devised by which this desirable result could be brought about at will. With this view he instituted a series of experiments, and established the fact that by passing sewage through a suitably porous soil, not constantly but intermittently, a high degree of purification could be ensured, the object of the intermittence being to aërate the filter and so give an opportunity for the purifying action of the oxygen. It is explained that a filter so used is not a mere mechanical contrivance, but a chemical apparatus for oxidising and thus altogether transforming, as well as for separating, the filth of dirty water.

"The Report (that of the Rivers Commission) says:—

"'These experiments on the filtration of sewage through various materials leave no doubt that this liquid can be effectually purified by such processes, and that probably any variety of porous and finely divided soil may be employed for this purpose.

"'With a properly constituted soil well and deeply drained, nothing more would be necessary than to level the surface and to divide it into four equal plots, each of which in succession would then receive the sewage for six hours. In this way the sewage of a water-closet town of 10,000 inhabitants could, at a very moderate estimate, be cleansed upon five acres of land, if the latter were well drained to the depth of six feet.'

"The number of persons to an acre proposed in this passage is

2,000, but Dr. Frankland afterwards estimated it might be increased to 3,000 or even more.

"The hint given by Dr. Frankland was immediately acted on by one of the most experienced sanitary engineers of the day, Mr. Bailey-Denton. A long and active employment on land drainage works had led him to observe the absorbent and cleansing powers of aërated soils, and the purity of the water issuing from deep underdrains, and he established a system of sewage treatment on the intermittent filtration principle at Merthyr Tydfil. The works were described in a subsequent report of the Rivers Pollution Commissioners; 20 acres of porous soil drained from 5 to 7 feet deep were prepared to take the sewage of 16,600 inhabitants and the effluent was stated to be satisfactory.

"These works were complicated by being combined with broad irrigation, but a few years later Mr. Bailey-Denton carried out a more positive example of the new principle at Kendal. Here he allotted a plot of 16 acres of very porous ground to take the sewage of 13,700 people, an allowance of about 900 persons to an acre. But the authorities of the town, wishing to try in the first instance the larger proportion, originally recommended by Dr. Frankland, began with only 5 acres, proposing to increase it if necessary. The land was well underdrained to 6 feet deep; it gave an effluent perfectly colourless and sweet, and it worked for some years fairly well, thus taking 2,740 people per acre.

"But, Mr. Denton protesting against the overtaxing of the soil, the filtering land was afterwards increased to 10 acres used intermittently, and the other six acres were irrigated with sewage on the ordinary plan. This, taking the whole, gives about 850 people to the acre, instead of 100 as allowed for broad irrigation. The effluent continues good, clear, and colourless.

"It was natural that a plan differing so materially from the ordinary mode of sewage application to land should be strongly criticised, and that objections should be raised against it. The Rivers Pollution Commissioners, in propounding the plan, suggested some objections that might be made to it, and these have been supplemented by others.

"They may be briefly stated as follows:—First, that the plan is wasteful, as not fitted for producing crops. Secondly, that the concentration of so large an amount of sewage on a small area will produce greater nuisance than other modes of treatment. Thirdly, that the soil receiving such large quantities of sewage will, after a time, become overloaded and clogged, so losing its filtering power. Fourthly, that the cost of preparing the land is so great as to preclude its adoption; and Fifthly, that the success of the process would be doubtful with ordinary management on a large scale.

"Mr. Bailey-Denton has given particular attention to these objections, and he has explained in his book of 1880 the result of ten years' experience in regard to them.

"In the first place, with the view of rendering the process more manageable, he has thought it expedient considerably to reduce the quantity of sewage which the originators of the scheme stated might be put on the land. Instead of allowing upwards of 3,000 people to the acre he limits the number to about 1,000.

"The first objection is that with such a large supply of sewage it would be impossible to grow crops, and that therefore the process would be unremunerative. This objection has been shown by Mr. Bailey-Denton to be, at least with the reduced quantity, unfounded. At Kendal, for example, out of the 10 acres used intermittently for filtration, 4 acres grow cabbages, 2 mangolds, 2½ carrots, and the remainder miscellaneous garden produce. In other places a similar result has been obtained.

"The second and third objections may be taken together. It was suggested that the collection of the solid matters of the sewage might give rise to a formidable nuisance, especially in hot weather, and might clog the pores of the land so as to prevent proper filtration.

"Experience has not warranted these fears; but at the same time it appears to be advisable previously to separate the solids to some extent. It is certain that the more the liquid approaches clarification the less land will be required, and the less danger will there be of unpleasant odours. For a small number of people, say under 500 to the acre, the sewage may be applied as it comes, leaving the grosser matters to become amalgamated with the soil. But if the number be increased, the previous removal of the sludge would be desirable, and for 1,000 or more it would probably become absolutely necessary.

"The fourth objection is as to the cost of preparing the land. There is no doubt that the proper laying out of the land is a very important element of success. Mr. Denton says:—

"'The preparation and formation of land to receive sewage should be effected *with precision*, and not in the careless way in which it is sometimes suggested sewage farms may be laid out. There is no economy in carelessly executed land preparations, and it is greatly to be regretted that such views have been inculcated.'

"It follows, therefore, that the cost of preparing land for this system must be greater than that for broad irrigation; but when the tenfold efficiency of each acre in doing work is taken into account, this can be well afforded. Mr. Bailey-Denton considers that the cost of preparing the filtration areas in the most difficult cases might amount to nearly £150 per acre, and in others it might be done for £30; the average he puts at about £70. The actual cost at Abingdon was £85.

"The fifth objection is a doubt whether the process would succeed with ordinary management on a large scale.

"It is obvious, from the description of the process, that common farming work will not do; the management must be careful and skilful to ensure the proper intermittency of application and regulation of quantity of flow, without which the system must act imperfectly.

"But whether this requires more than can be reasonably and perfectly done at a moderate expense is a question of experience; and this, so far as it has gone, appears not to favour the objection.

"It will be now understood that the essential difference between the intermittent filtration system and that of ordinary broad irrigation is as follows:

"Broad irrigation means the distribution of sewage over a *large* surface of ordinary agricultural ground, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage supplied.

"Filtration means the concentration of sewage, at short intervals, on an area of specially chosen porous ground, as *small* as will absorb and cleanse it; not excluding vegetation, but making the produce of secondary importance.

"The intermittency of application is a *sine quâ non* even in suitably constituted soils, wherever complete success is aimed at. No instance of failure, says Mr. Denton, can be pointed out where careful underdrainage and suitable preparation of surface with proper periods of rest have been adopted; whereas the cases are unfortunately becoming numerous in which defective effluents are discharged, and considerable nuisance is created on the surface, when large quantities of sewage are poured on without regulated periodical application.

"Mr. Bailey-Denton attaches great importance to the judicious combination of intermittent filtration, as a certain means of purifying foul liquid, with surface irrigation as the only means of utilising sewage to the full extent possible, the former serving, so to speak, as a safety-valve for the latter.

"He has carried out works on this principle at Abingdon, Malvern, Barnsley, and elsewhere, and has given a table in Q. 18,653 of a number of places in which the intermittent system has been used, either alone or in combination.

"In regard to this combination he says:—

"'If instead of leaving sewage when applied to land to flow where it will, over irregular surfaces in the varying quantities in which it is usually discharged from towns, proper steps were taken to deliver for surface irrigation only such quantities as are wanted by the cultivator, by taking advantage of the power we always possess of cleansing any quantity of sewage by intermittent filtration through a small area of land, not only would sanitary authorities conform to the requirements of the law in relation to the purification of their sewage with a *less charge upon contributing ratepayers than is involved in any other treatment*, but agriculture would secure a benefit in its profitable utilization at present withheld.'

"He also remarks:—

"'That by adopting properly devised intermittent filtration areas which allow of no overflow from the surface into rivers, nor any discharge but from the underdrains (except in times of excessive rainfall, and then only by regulated storm overflows), the constantly recurring evils due to inattention on the part of those who have the care of the disposal works, are completely removed.'

"The following conclusions, drawn up by so experienced an authority, will throw light on some important points connected with this matter.

"'That where agricultural land can be obtained for the purpose at a cost not exceeding 50 per cent. above its ordinary saleable value, resulting in a rent-charge not exceeding £2 10*s.* an acre, the sewage should be applied to it on the principle of surface irrigation on a wide scale, combined with intermittent filtration; and if the extent does not exceed that which will satisfy the demands of local markets for vegetables and grass produced from it, an immediate return may be expected sufficient to pay all outgoings, including the renting charge.

"'That where land can only be obtained at a price involving an annual charge of £10 an acre and more, a sanitary authority is only justified in acquiring just sufficient land to secure a permanent cleansing of the sewage, which may be limited to one acre for every thousand of the population, always assuming that the land is quite suitable, that it is naturally or artificially underdrained to the full depth of six feet, and properly prepared to receive the sewage, and that the sewage is applied quantitatively and intermittently.

"'In applying sewage to land for irrigation, the wider the area beyond the

quantity that will meet the demands of local markets for sewage produce, the greater will be the loss upon the present ratepayers.

"'Sewage farming can never be remunerative to the Sanitary Authority who lets, nor to the farmer who hires the sewaged land, so long as the latter is compelled to take and cleanse the sewage at all times and under all conditions. It is therefore essential that a properly prepared plot of land for intermittent filtration should be held by the Local Authority to receive the sewage when not wanted by the farmer.

"'The practice of loading land laid out for irrigation with excessive quantities of sewage should be strictly avoided, as one subversive of the law in respect to river pollution, and opposed to economical results from sewage utilization; this point will be gained by the provision of a properly prepared plot of land for the intermittent filtration of the sewage which is in excess of the quantity actually required.

"'Land receiving sewage should be most carefully prepared to distribute it while in a fresh condition. All half and half measures result sooner or later in river pollution, and loss to the ratepayers.'

"We may now compare this process with the former one of broad irrigation in regard to the three questions: *Will it produce effectual purification? Will the process be in any way objectionable? What will be its cost?*

"(1) As to the *purity of the effluent*, the Rivers Pollution Commissioners said, 'it would be difficult to decide between filtration and irrigation;' but there are some reasons why the filtration process would seem to have the advantage. In the first place, the system and motive of working would be totally different, the purification being the principal thing aimed at, and the vegetation only secondary and subsidiary, so that the attention of the management would naturally be directed to the quality of the effluent as the chief aim.

"Moreover, in filtration ground properly laid out, there ought to be no communication between the influent and the effluent channels except through the pores of the land, so that the sewage, in order to get away, must necessarily pass through the filter. By this means the process of purification becomes not optional (as in broad irrigation), but compulsory. And supposing the persons working the farm had at any time an inducement to pass away the sewage unfiltered, they could hardly do so without such a derangement of the works as would attract immediate attention.

"(2) In regard to the *liability to objection*, we believe this process has the advantage over broad irrigation. For the liability of nuisance would, if the sludge were previously removed, be reduced by the smaller area of land exposed; and the danger to subsoil waters would be diminished by complete and skilful underdrainage.

"(3) The *cost* of the process is materially affected by the much smaller quantity of land required.

"It would perhaps, hardly be safe to adopt Dr. Frankland's estimate of 3,000 people to the acre, as no such number has been subjected to practical trial, except on the very small experiment at Kendal. The quantity will depend materially on the nature of the land, but as a general estimate it would be safer to take Mr. Bailey-Denton's more moderate estimate of 1,000 to the acre, which is ten times the number usually allotted to broad irrigation.

"The cost of preparation per acre would, as we have already remarked, be increased, as would also the cost of management, and the returns of produce would be of course much less.

"Still on the whole, there would, no doubt, be a large saving over the cost of broad irrigation.

"With regard to filtration through land, we are of opinion—

"1. That the process has great scientific merit, and offers valuable practical advantages for the disposal of sewage in situations where broad irrigation is impracticable, and where land suitable for filtration can be obtained.

"2. That, however, it appears desirable, when the area of land is considerably reduced, that the sewage should be previously treated by some efficient process for removing the sludge.

"3. That an arrangement of this kind would be applicable to the metropolis, as we shall explain more fully hereafter."

Since the publication in 1880 of the first edition of this treatise, the author's firm (Messrs. Bailey-Denton, Son, and North) have laid out several additional sewage farms on the principle of Intermittent Downward Filtration through natural soil, *per se*, and in combination with Broad Irrigation, and as it is probable that a description of them would strengthen the conclusions which have been already come to from perusing the statements already given, the author has selected for publication three representative cases to illustrate the progress made. They lengthen the period of experience from ten to fourteen years, and cannot fail to show what may be done by Local Authorities to remove the doubts and difficulties which have resulted from the indecision prevailing with the highest authorities. But before entering upon these details the author has thought it better to explain the present condition of the several farms which formed the subject of the first edition. He will do so in the order in which they originally appeared.

1. MERTHYR TYDFIL, GLAMORGANSHIRE.

It will be remembered that in this case the District Authority had committed itself to the purchase of 375 acres of land for Merthyr Tydfil alone, with its population of 50,000, with the intention of utilising that area for Broad Irrigation, but that in consequence of the success that attended the laying out by the author of 20 acres (a part of this land) for Intermittent Filtration, and the discovery therefrom that it was much more economical to adopt Intermittent Filtration *per se*, or in combination with Broad Irrigation, than Broad Irrigation alone, an arrangement was made to bring into combination with Merthyr Tydfil the districts of Aberdare, Mountain Ash, and Treharris (Quaker's Yard), with a

united population of 100,000. On this combination being made, instead of 375 acres being required for Merthyr and its 50,000 persons alone, it was found that a less area would suffice for the combined districts with their 100,000 persons.

On the 14th of June, 1884, Mr. Harpur, the local engineer and surveyor of Merthyr, in reply to an inquiry, obligingly informed the author that the quantity of land sewaged for the combined districts was 336 acres, and that the return obtained from that area over and above the expenditure upon it, and exclusive of rent, was for the year ending 25th of March, 1884, £452 9*s.* 7*d.*—not a bad rent. In the same month (June, 1884) the medical officer of the district wrote, saying, "the Troedyrhiew areas do their work thoroughly."

2. KENDAL, WESTMORELAND.

This farm, which was originally laid out by the author, and consisted of only 5 acres, having been increased to 10½ acres (see original statement), with 2 additional acres used for Rye Grass, and 3¾ acres as ordinary meadow, still continues to do its work very well, and to the satisfaction of every one connected with it. Mr. Banks, writing on the 26th August, 1884, says: "I have now given up being Borough Surveyor here, and have discontinued the management of the farm. A committee have it in hand. I, however, take great interest in it, as I think it one of the most successful schemes for dealing with sewage that there is in the country."

3. ABINGDON, BERKSHIRE.

On the 27th of May, 1884, the local surveyor wrote as follows:—"In reply to your letter of yesterday, I have to state that the Council thoroughly approve of the mode you adopted for the disposal of the sewage. We have not received at any time any complaint as to any local nuisance. The whole of the farm is let for £4 10*s.* per acre. The tenant of the farm objected to the solid ingredients of the sewage being removed from the liquid, saying that 'the richer the sewage the better I like it.'"

4. FORFAR (SCOTLAND).

The account of this farm is even more satisfactory than that of Abingdon. The manager, writing to the author in the early part of

1884, stated that there was a balance in favour of the farm for the year 1882–3 of £247 6*s.* 2½*d*; adding, "the farm is giving every satisfaction, and the effluent is always quite clear." For the year 1883–4 the following, statement extracted from the Annual Official Statement, shows the revenue and expenditure:—

REVENUE.

	£	*s.*	*d.*
Barley	12	6	6
Carrots	15	7	3
Hay	3	18	0
Turnips and mangolds	193	12	7
Grass	189	1	11
Sand and Gravel	48	8	10
Rent of Inchmacoble grass field	27	0	0
Half-year's rent of Orchardbank House ...	15	0	0
Total revenue	£504	15	1

EXPENDITURE.

	£	*s.*	*d.*
Horse labour	31	9	0
Manual labour	155	9	10
Seeds	9	3	2
Auctioneer's commission, &c.	14	18	7
Printing, &c.	1	3	0
Farm implements and repairs of tools	5	6	0
Painting Orchardbank House	3	5	5
Total expenditure	£220	15	0

Revenue ...	£504	15	1
Expenditure ...	220	15	0
	£284	0	1

"The balance of revenue over expenditure, considered as rent for the farm, which extends to 38 acres, is equal to the sum of £7 9*s.* 6*d.* per acre. As compared with the previous year, the result shows a net increase of revenue over expenditure of £36 13*s.* 10½*d.* The yield from barley and carrots is less—in the one case by £5 8*s.* 4*d.*, and in the other by £12 3*s.* 4*d.*; but turnips and mangolds have brought £23 11*s.* 5*d.* more than last year, and grass £16 0*s.* 11*d.* No cabbages were grown on the farm this year. The income from this source was £17 11*s.* 8*d.* last year. The sum received as rent from the Inchma-

coble grass field shows an increase of £8, and the proceeds from sand and gravel have been higher by £13 18*s.* 10*d.* Last year £30 was received as rent from Orchardbank House, but only £15 has been received this year. On the expenditure side a reduction has been effected of £8 10*s.* The year's result of the Sewage Farm, as seen from the balance-sheet, must be considered highly satisfactory."

This account, though extremely satisfactory to the author, is not more so than the report of Mr. Alexander Campbell, inspecting officer to the Board of Supervision, Scotland, who, having visited the farm, publicly advised all Sanitary Authorities to pay it a visit and judge for themselves. He says: "To ensure success it is requisite that the work should be skilfully designed and executed, and afterwards properly superintended. In both these respects the Local Authority of Forfar have acted wisely. The engineering was entrusted to the firm of Messrs. Bailey Denton and Co., who have made it a speciality; and the services of Mr. Jonas Harris, sent down by the engineers to carry out the work, were permanently secured to superintend it when finished, and to work the farm. . . . It will be observed that the farm is charged with 4 per cent. on £4,000, the purchase money of the 40 acres, which makes a very high rent per acre; with 4 per cent. on £1,500, the expense of the engineering works, and with the ordinary working expenses; and that, after paying all this, a profit remains. Local Authorities with whom the financial question is all important, should consider this well. They will here find a great sanitary benefit obtained, and combined with it a commercial success. Lord Strathmore, in forbidding the further pollution of the loch, has thus conferred a benefit on the inhabitants of Forfar, and *riparian proprietors may from this be encouraged to take all necessary steps to secure the purity of our streams and rivers by enforcing the provisions of the Rivers Pollution Act.*"

5. GREAT MALVERN.

In this case Mr. Palmer, the local surveyor, wrote on the 29th of March, 1882, as follows:—"I am glad to say the works are very satisfactory—the areas are performing their work well, and the effluent is all that can be desired. The income (1882) about balances the expenditure."

In 1884 the District Accounts show that there was a balance *in favour of the farm* of £162 15*s.* 1*d.*, which was carried to the credit of the District Rate.

6. HALSTEAD, ESSEX.

In this case, where an unsuccessful attempt was made to introduce wind as a motive power for pumping, little is to be said beyond the fact that a good rent has been obtained from the land which is not likely to continue for long, inasmuch as the Board have agreed, the author understands, to plant all the filtration areas with osiers, the roots of which will in time fill the drains. It is needless to say, after the remarks on Osier Beds, which appear in Chapter IV of this treatise (First Edition), that this proceeding is opposed to the advice of the author.

The distance of this little farm from the town, and the fact that there exists no buildings upon the land, much reduces the chances of a favourable letting. Nevertheless the whole of the land is now let with the sewage for £80 a year, or more than 2 per cent. on the cost of the land and preparation.

7. BARNSLEY, YORKSHIRE.

This farm, which it will have been seen in the original edition consists of a loamy "clay," and is therefore not so porous in subsoil and free in action as is desirable, is still satisfactory.

The manager writes on June 5th, 1884: "The farm is not yet paying its working expenses, but there are now no complaints whatever from adjoining landlords, nor any threats of a renewal of proceedings in the Court of Chancery."

This, it will be seen, is a case in which the surface waters to a great extent find their way into the sewers and very largely increase the quantity of liquid to be dealt with. This is very unfortunate where the land is of a clayey character. Though the population is now less than 30,000, the quantity of liquid sewage often reaches 1,000,000 gallons in 24 hours.

8. HITCHIN, HERTFORDSHIRE.

The result in this case cannot be more appositely expressed than in the words of the Chairman, who, in May last (1884), stated that "he did not think that any town in the kingdom could show a more satisfactory state of things as regards sewage disposal," followed as that encomium was some months after by the following account given in the proceedings of the Board:—

"Mr. A. Ransom read a comparative statement, showing the quantity of liquid delivered from the town sewers at various hours of the day in the

year 1883, and at the same season in the present year. The quantities varied from two-thirds to one-half in 1884 to what it was in 1883. Mr. Ransom said the land was fully equal to deal with all that was now delivered to it." The account goes on to state—

"It is only due to Mr. Denton, who laid out the farm as engineer to the Board, to say that he always contemplated the diversion of extraneous water from the sewaged land; but this part of his scheme was not fully carried out, the consequence being that, owing to excessively wet seasons, a large amount of subsoil drainage water found its way into the sewer, thus deluging the farm and preventing the land doing its work. This season, however, has been so dry that probably not much beyond the normal quantity of sewage has found its way to the farm, and thus the farm has for the first time had a fair chance of proving its efficiency, which, according to the statement of the Committee, it has now done. It is only just to Mr. Denton that this statement should be made."

9. OAKHAM, RUTLAND.

There is nothing whatever to add to what has already been said as to Oakham and the remaining cases described in the first edition of this treatise; though it is satisfactory to state that Mr. Finch, of Burley-on-the-Hill, M.P. for the county of Rutland, the owner of the town of Oakham, has himself continued to cleanse the sewage on the same land, and wrote to the author in June last (1884) stating that he was quite satisfied with the result, both as regards the disposal of the sewage and the return obtained.

The author did not execute the works. They are referred to here because they exemplify what an *owner* has successfully taken upon himself to do.

The following are the selected cases that have been dealt with since the date of the first edition (1880):—

DEWSBURY, YORKSHIRE.

This case is of considerable interest owing to the fact that Dewsbury is a manufacturing town of importance on the River Calder, and that "middens" (closets) are chiefly used by the inhabitants. The population is about 30,000. The quantity of trade liquid of no manurial value to be disposed of, either by admission into the sewers and treatment on the land or otherwise, is very considerable, whilst the quantity of solid fæcal matter of value as manure is comparatively small.

The quantity of land prepared for filtration is 50 acres, with rather more than 10 acres for surface irrigation; the whole area utilised including banks, roads, &c., being over 70 acres. The land here referred to consists of the greater portion of Mitchel Lathes Farm. The soil, for the most part, is very porous and of a sandy character, very suitable for filtration. The work of preparation has been more than ordinarily expensive owing to the necessity of forming the surface into comparatively few horizontal areas, which involved the removal of a great quantity of earth; yet the cost on the whole has not exceeded £110 per acre. There has been considerable expense incurred in substituting a new outfall channel for the Chickenly Beck (which before ran through the farm), and in the construction of roads, besides the erection of a wall as a boundary. The principal feature of this farm is its evident capability of serving for the cleansing of much more sewage than is discharged from Dewsbury alone if the surface waters be carefully excluded from the sewers and the trade liquid properly treated. There is no doubt whatever that if the numerous chemical ingredients used in the trades of Dewsbury were altogether excluded, and solid flocculent refuse properly screened from the liquid before it reaches the land, it would absorb and cleanse nearly any amount of liquid that could be applied to it. At present, however, contrary to the advice of the author, no means have been adopted to separate the solid matters from the liquid sewage, and the consequence is that the furrows by which the sewage is distributed hold matter which is extremely objectionable without being beneficial to vegetation.

The farm manager on the 25th of May, 1884, wrote to the author saying: "The sewage farm is doing better this season than before, and the crops are looking very fair, but we cannot expect very heavy crops as the land is very poor, some of it having been cropped four times without having manure of any kind. The sewage consists chiefly of dye wash; nevertheless the effluent is very good, and every one that sees it is surprised to see how clear it is. There are a great many mill hands come to have a bathe at the outlet, it being the only clear water for miles that they can bathe in." This fact is striking because it was from this part of the River Calder that the Rivers Pollution Commission took the *water* wherewith to write their "Memorandum" showing the condition of the river.

WITHINGTON, LANCASHIRE.

The next case is that of Withington with Levenshulme, which together present a case of some interest owing to the locality being in close proximity to Manchester, our greatest commercial centre, and to the River Mersey, a stream which is befouled by sewage to perhaps a greater extent than any other river in the country. The present population of Withington and Levenshulme, contributing sewage to the farm, may be taken at 21,000; it has been proposed to add the district of Rusholme with its population of 12,000, which together would raise the present population to 33,000, whilst there exists a prospect of rapid increase from the proximity of the combined districts to large and populous towns. The whole case is one of an instructive character.

The filtration areas are designedly laid out to purify daily *one million gallons of sewage*,—which is a very liberal allowance for a future population of 40,000 persons,—with an arrangement whereby any excess of that quantity in times of heavy rainfall may be discharged into the River through Osier Beds which it is hoped will secure *clarification*. There are no manufactories in the district, and middens exist to some extent. The old sewers are leaky and let in subsoil water which renders the sewage now discharged more diluted than ordinarily.

The land selected for the treatment of the sewage is situated close to the Mersey at the point where the Chorlton Brook joins that river. Before embankment this land was subject to frequent flooding. The soil is an alluvial deposit, partly of a free character, well adapted for filtration, and partly of a loam inclining to clay, which, though porous as clay, is very much less active than the remainder of the farm. The quantity laid out in level areas and osier beds consists of 78 acres separated from the main valley by a cross bank from the existing river bank to that of the brook. The construction of this new bank and the strengthening of the old ones have necessarily formed a considerable item in the expenditure. The whole of the utilised land has been drained about 5 feet deep, at intervals between the drains varying according to the porosity of the soil, and the drained effluent is discharged by a 3 feet earthenware culvert passing under the Chorlton Brook into the Ousel Brook below the Stretford (flood water) Weir.

Of the 78 acres 49 only are laid out for filtration, the remaining 29 acres being appropriated to Osier Beds, enbankments, and roads, with some marginal land outside the embankments not utilised at all.

The total outlay in preparation has been £12,887, but if from this amount there be deducted the outlay on the banks, and the construction of the outfall drain into the Ousel Brook, the cost per acre would not exceed £118. The outlay, moreover, was very sensibly increased by the difficulties attending the position of the land and the somewhat frequent floods that occurred during the operations. The farm is at present in the hands of the Local Board. It is quite possible that the quantity of sewage has been increased with advantage to the present ratepayers of Withington, inasmuch as all parties contributing additional sewage will be made to pay in relief of those who now are charged with the outlay already incurred, whilst an excellent and an increasing market for the produce of the farm will always be found in the city of Manchester. Thus the benefits now derived at Merthyr by the extension of the contributing population may be experienced at Withington (see Merthyr). It should be stated that in the design adopted at Withington the system of underdrainage was so laid out as to allow of an increased number of lateral drains, whenever increased capability of absorption may be required, without prejudicial effect. Mr. Joseph Swarbrick, Assoc. M. C. E., the local surveyor, rendered every assistance in carrying out the works.

WATFORD, HERTFORDSHIRE.

The last additional instance it is desirable to give represents the drawbacks and advantages which attend a very large class of works where land is resorted to. It is that of the district of Watford, with a population of over 12,000 persons (1884).

In the beginning of 1881 the Local Board of Watford was subject to proceedings in Chancery by Mr. Snewing, a neighbour, who sought an injunction to restrain the Board from continuing to pollute the River Colne by allowing the sewage of their district to pass into that river, and the author was called in to advise the Board as to the best means to be adopted to prevent this. The sewage was at that time treated on about 15 acres of land by ordinary irrigation, whereby the liquid with certain ingredients passed over the surface and found its way into the river only partially cleansed. The 15 acres were made up of 10 acres of rapidly sloping arable ground, and 5 acres of flat meadow land adjoining the river, whilst the soil of which the former was composed was of a very irregular and mixed nature, consisting of beds of clay, gravel, and sand, with the underlying chalk rising up in places to within a few feet of the

surface, whereby any liquid penetrating the overlying earth when it reached the chalk would find its way to the lower depths of that formation.

It being desired by the Local Board that the area of land utilised should be increased as little as possible, the low flat land was laid out (undrained) for osiers to receive flood and excess waters, and the 10 acres of arable already utilised, together with 4 additional acres of adjacent land, were by the author's advice prepared, drained, and aërated in horizontal terraces to absorb the sewage, so that that which had previously run over would necessarily pass through the soil to the underground channels which were laid to convey it in a purified condition to the river. The area being comparatively small—one acre to each 850 persons—the author, as engineer, made it a precedent condition that all solid matter should be separated from the liquid before it was delivered to the filtration areas, and the Board agreed to do this. He also required, as a *sine quâ non*, that all foreign water that could possibly be excluded from the sewers should be removed; thus rendering the liquid which had to be cleansed by filtration as free from flocculent matter and as reduced in quantity as possible.

The preparation of the land was duly executed, and the whole of the sewage of Watford has since been cleansed by passing through 14 acres of land, in spite of the fact that the precedent conditions insisted upon have not been fully carried out and yet require fulfilment. Nevertheless the late chairman, Mr. C. F. Humbert, a gentleman of great practical experience in the management of landed property, stated in February last (1884), at one of the last meetings over which he presided, that "when the works came from Mr. Denton's hands they were a decided success," and it is indeed to be regretted that, in an example of such great importance to the people of Watford and to the country at large, pains should not have been most carefully taken by the Local Board to develop Intermittent Filtration in accordance with the principles upon which that method of treatment was founded, and upon which its success depends.

The existence of chalk underlying the terraces has been made the ground of declaring that the underdrainage was useless (underdrains are as useful for aërating the soil as for discharging liquid), and osiers have actually been planted on the drained terraces, because their cultivation involves less expense than the labour incident to ordinary cropping.

(Cultivation of the surface of filtration areas is necessary to ameliorate and comminute the soil for the even absorption of the sewage.)

At Watford the solid part of the sewage, only partially removed from the liquid, has been thrown out of the tanks upon adjacent ground where it has been left to putrefy and dry, without any attempt being made to render it fit for removal by the process of pressing or otherwise. The collection of this putrescible matter is constantly giving off effluvium objectionable to the neighbourhood, and as this takes place close to the land utilised for filtration, it has given the farm a character which is in no way due to it; for it can be proved to demonstration that no smell emanating from the land can be discovered 50 yards from its margin.

Watford is especially a case to be studied by the sanitary engineer; the sewage of 12,000 persons has already been delivered to, distributed upon, absorbed by, and filtered through 14 acres of land for many months together, with only the occasional relief which has been afforded in times of excess of rainfall, when the sewage has been removed from the terraces and run through the osier beds, and lower land prepared for the purpose. Watford is, in fact, a case where the existence of a deep porous substratum, serving as an absorbent of the liquid which has passed through the upper crust of soil, may become a source of great evil, if the aëration due to the underdrains be checked, the surface soil not cultivated nor made productive of vegetation, whilst the sewage itself is applied without the required intermittency.

In publishing the second edition of this treatise, the author desires to express as strongly as he can his conviction—confirmed by his practice since the date of the last edition (1880)—that intermittent filtration, when properly designed and executed, cannot fail in its purpose, if maintained and managed with strict regard to the principles upon which the process is based. At the same time he is compelled to admit that it will assuredly fail, or at any rate will not be satisfactory, when the filtering beds or areas, to save expense, are not prepared with precision, or where the subsequent treatment, in relation to the quantity of sewage applied to a given area, and its intermittency of application, are disregarded. There is no economy, but absolute waste, in rejecting those rules and observations which will ensure the distribution of the sewage evenly over the surface, and through the soil of the beds, in quantities regulated by the character of the subsoil, and the freedom with which liquid will infiltrate.

There is an observation which the author desires to add to the "conclusions" he previously arrived at and expressed (see page 101) in the first edition of this treatise. It is this: that although he considers that where suitable land of sufficient extent can be obtained it is better and more economical to convey the finer floating ingredients (sludge) to the land by the ready carriage of the sewage itself, there is no doubt whatever that, if those floating ingredients be entirely extracted from the liquid by chemical precipitation or mechanical deposition, the liquid so clarified will pass through the same soil—relieved as it will be of all coating matter—with very much greater rapidity. It is true that "sludge" is always acceptable to the sewage farmer, by reason of the manurial qualities it possesses, and that the mineral ingredients (road detritus, &c,), which sludge invariably contains, are valuable for improving the texture of the land for filtration; but it is equally true that clarified sewage will pass through suitably constituted soil, thoroughly aërated, without any impediment other than that due to the closeness of its interstitial spaces, and that to secure purity the finer those aërated spaces are the more certain will be the result. Reduced to figures it may be taken that the same land will filter double the quantity of clarified sewage liquid that it would cleanse sewage of which the finer particles have not been removed.

Applying these observations to the great object to which the Royal Commission on Metropolitan Sewage Discharge devoted its attention, —the purification of the Thames,—it may be assumed without doubt, that the *clarified sewage of* 2,000 *persons* may be purified on each acre of suitable land to which it may be applied; or, in other words, that if a future population of $7\frac{1}{2}$ millions has to be provided for, it only requires 3,750 acres, or say 6 square miles, of suitable land to satisfy the requirement. If less than 2,000 persons to an acre be taken as the basis, the quantity of land will, of course, be proportionately increased.

It is further the wish of the author to express his belief that there exists in the rising ground on the Essex side of the Thames Meadows, between Barking and Tilbury, ample area for purifying the clarified sewage of the whole of the metropolis, without causing any *real* nuisance of any kind.

To avoid sentimental—in contradistinction to sound—objections, which might be raised to Sewage Farms in the present instance, it would only be necessary to purchase, under the Lands Clauses Con-

solidation Act, a marginal breadth of clearance land, outside the sewaged area, to which no sewage would be applied.

That the land pointed out is suitable for the purpose of intermittent filtration has been already signally proved by what has been done in the way of disposing of sewage at the Lodge Farm near Barking, where London sewage was applied, and at Breton's Farm, where Colonel Hope utilised the sewage of Romford. Both these farms are situated on the rising ground that has been pointed out as suitable for the cleansing of the sewage of the metropolis.

In the case of the Lodge Farm, Mr. Morgan has stated in his published reports that such was the porosity of some portions of the farm that 451 tons of sewage had to be expended in the production of one ton of grass, and that he had applied in twelve months as much as 21,488 tons *per acre*, which is equivalent (at 20 gallons per head) to the sewage of a population of 660 to the acre. At Breton's Farm Colonel Hope so arranged the application of the Romford sewage to the land, which was thoroughly drained, that the effluent water was returned to the tanks to be re-applied with the daily outflow of sewage from the town.

In both these cases the figures represent the quantity of sewage absorbed where the immediate object of the application was not the cleansing of sewage by filtration, but the production of vegetation by irrigation; and it may be regretted that such facts as these, which show so distinctly the remarkably absorbent powers of the soil, were not elicited by the Royal Commission, for they would go far to satisfy the most sceptical that the land pointed out is capable of purifying the sewage of the metropolis, and at the same time of securing an appreciable return in the shape of vegetable production.

INTRODUCTION TO FIRST EDITION.

THE following treatise, explanatory of what has been done by the author in the way of cleansing sewage by filtration through natural soil, is intended to satisfy sanitary authorities that wherever land is to be obtained, in a greater or less quantity, they have it in their power to prevent the pollution of rivers, at a comparatively moderate outlay, and that they may do so with advantage to the country generally by increasing our food production.

At the same time he desires to impress his readers with the fact that he recognises in the dissimilar conditions affecting some towns and districts ample reason for difference in the treatment of the sewage discharged from them, and for a varying degree of purification of the effluent.

With that view he ventures to reprint here from his lectures on "Sanitary Engineering," given before the School of Military Engineering at Chatham (1876), the following passages on the classification of towns and villages according to the nature of their outfalls:—

"All towns in this country may be placed in one of these classes, viz.: (1) towns on the sea-board, (2) towns on estuaries and tidal rivers, and (3) towns on inland rivers and tributary streams. I will deal with them under these heads, and add a few special remarks upon the disposal of sewage from villages and hamlets.

"(1.) *Sea-board Towns.*—In the economy of discharging sewage directly into the sea, in the case of towns situated on the sea-board, a good and sufficient reason exists for the adoption of that means of disposal wherever it can be done without injuriously affecting the shore. The probability is, however, that the floating matters will return, and that the soluble matter will mix with the sea so as to pollute the shores, and in sea-bathing towns such a result should not be possible. The possi-

bility of discharging sewage into the sea unobjectionably only exists where the shore is not used for bathing or for recreation, and where the town does not extend down to the water's edge. Where it stands well above the sea level, and the outfall sewer may be carried far into the sea without converting such sewer into a sewage-reservoir, the arrangement may be effected advantageously.

"In cases where the sewage is impounded within the outfall sewer for a period of time during each tide, not only is the sea-shore too frequently affected in a manner to prejudice the interests of a sea-bathing town, but the inhabitants are injuriously affected by the generation and evolution of gases from the impounded sewage which find their way by the communicating sewers into the houses, and by the gullies and gratings into the streets during the time the sewer mouth is closed. Brighton may be taken as an illustration of this state of things.

"While the average death-rate of healthy districts is 17 per 1,000, that of Brighton frequently rises above 20, and this excess is only to be explained by the character of its sewerage, the detention of the sewage in the outfall sewer, the mode of disposal, and the overcrowding of dwellings; for the town possesses all the advantages due to a southern aspect, an open sea, and a wide reach of downs to shelter it from cold wind whilst affording to the inhabitants the means of healthful exercise.

"It will have been anticipated from these remarks that, even in sea-board towns, the sewage, before it is discharged, should not only be clarified, but that everything should be done within reasonable limits to secure a constant outflow independently of the tide. . . . .

"One or other of the tried chemical precipitation processes will effect the required clarification of the sewage of this class of towns where land cannot be obtained.

"(2.) *Towns discharging into Tidal Rivers and Estuaries.*—A considerable number of towns in this country are situated on the shores of tidal waters, some of which reach far inland. The difficulty of satisfactorily dealing with sewage which can only be carried to the sea by the ebb of the tide, is very considerable.

"The banks or shores of these waters generally consist of mud, and are exposed to the atmosphere for a sufficient time during each tide to give off in extremely hot weather an intolerable stench, which is necessarily made worse by mixture with sewage. In dealing with towns on tidal rivers it becomes the duty of the engineer to treat the

liquid refuse differently from the way in which he would dispose of the sewage of either a town situated directly on the sea-board, or on an inland river.

"The most rational view of the matter is that, while the sewage discharged from sea-board towns directly into the sea may be simply clarified: that which is discharged into tidal rivers, the waters of which are not potable should be cleansed of its putrescible matters up to a certain standard, which, though less stringent than that applied to inland rivers, should be sufficiently high to prevent nuisance.

"The standards recognised by the Conservators of the River Thames, as applicable to districts below the intakes of the London Water Companies, may be adopted for this class of towns. They say of the defæcated water to be discharged from these districts—

"'1. It should be free from an offensive odour.

"'2. It should be free from suspended matters, or, in other words, be perfectly clear.

"'3. It should not be alkaline to turmeric-paper, nor acid to litmus paper.

"'4. It should not contain per gallon more than 60 grains of solid matter dried at 260 deg. Fahr.

"'5. It should not contain more than three-quarters of a grain of organic and ammoniacal nitrogen per gallon.

"'6. It should not contain more than two grains of organic carbon per gallon.

"'7. It should contain not less than one cubic inch of free oxygen in a gallon."

"It should be observed, however, that one of the eminent chemists who signed this recommended standard, Dr. Frankland,—himself a member of the Rivers Pollution Commission,—added these words: 'The conditions under which fluid which has been contaminated with sewage may be admitted into the Thames, as prescribed in the foregoing report, will, I have every reason to believe, preserve the river from being offensive to the inhabitants upon its banks; but, whilst thus far agreeing with my colleagues, I wish it to be distinctly understood that, in my opinion, such fluid can only be safely admissible into the Thames on condition that the water is not afterwards used for domestic purposes.'

"These standards—which, as the Government do not recognise them, are only now useful as indicating the very reasonable view taken

by the Thames Conservancy Board—can, it is declared, be reached by several of the chemical processes now in existence. In the case of tidal rivers which reach far into the country, and the banks of which are exposed at every tide and give off effluvia of increased offensiveness when the tidal water is mixed with sewage, however, it is not only desirable in many instances to separate the solid matters and clarify the liquid as chemical precipitation will suffice to do, but to purify it also.

"How far the Rivers Pollution Prevention Act may affect towns on tidal rivers remains yet to be seen. In Part II, section 3, it is laid down that 'every person who causes to fall or flow, or knowingly permits to fall or flow, or to be carried into any *stream* any solid or liquid sewage matter shall (subject as in this Act mentioned) be deemed to have committed an offence against this Act. Where any sewage matter falls or flows, or is carried into any stream along a channel used, constructed, or in process of construction at the date of the passing of this Act, for the purpose of conveying such sewage matter, the person causing, or knowingly permitting the sewage matter, so to fall or flow, or to be carried, shall not be deemed to have committed an offence against this Act if he shows to the satisfaction of the Court having cognisance of the case that he is using the best practicable and available means to render harmless the sewage matter so falling or flowing, or carried into the stream.' In Part IV of the same Act it is stated that '"*Stream*" includes the sea to such extent and tidal waters to such point as may, after local inquiry, and on sanitary grounds, be determined by the Local Government Board, by order published in the *London Gazette*. Save, as aforesaid' (the exceptions are the Lea and Thames, which are under special control, and the sea or tidal waters the use of which for the discharge of sewage has been sanctioned by Act of Parliament), 'it includes rivers, streams, canals, lakes, and watercourses, other than watercourses at the passing of this Act, mainly used as sewers and emptying directly into the sea, or tidal waters which have not been determined to be streams within the meaning of this Act by such order as aforesaid.'

"(3.) *Inland Towns.*—It is not only reasonable but positively necessary that considerations altogether different from those ruling in the case of sea-board towns should determine the mode of disposing of the sewage of inland towns. The effluent water in such cases should indeed be freed of all foul or noxious matter (Public Health Act, 1875, clause 17), without compromise, and the law should be exercised without hesitation.

"The influence of the opposition of manufacturers has resulted in a temporary respite, and some ground has been lost by temporising which had been previously gained by slow and certain steps; but when saying this it is impossible to evade the conclusion that the perfect and permanent cleansing of sewage will be sooner or later insisted upon by every voice in the country, and by no persons more decidedly than by the manufacturers themselves. The standards suggested by the Rivers Pollution Commissioners, at first adopted, then abandoned, by the Government of the day, but which, nevertheless, afford a very good indication of what may satisfy future requirements, precluded the admission of the following liquids into any stream.

"(*a.*) Any liquid containing in suspension more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter in 100,000 parts by weight of the liquid.

"(*b.*) Any liquid containing in solution more than two parts by weight of organic carbon, or ·3 part by weight of organic nitrogen in 100,000 parts by weight.

"(*c.*) Any liquid which shall exhibit by daylight a distinct colour when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel.

"(*d.*) Any liquid which contains a solution, in 100,000 parts by weight, more than two parts by weight of any metal except calcium, magnesium, potassium, and sodium.

"(*e.*) Any liquid which, in 100,000 parts by weight, contains, whether in solution or suspension, in chemical combination or otherwise, more than ·05 part by weight of metallic arsenic.

"(*f.*) Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than one part by weight of free chlorine.

"(*g.*) Any liquid which contains, in 100,000 parts by weight, more than one part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.

"(*h.*) Any liquid possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1,000 parts by weight of distilled water.

"(*i.*) Any liquid possessing an alkalinity greater than that produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

"Where these standards have been reached for a continuance by any

single treatment of sewage it has been effected by recourse to land, either by way of wide surface irrigation, or intermittent downward filtration. When local circumstances forbid the acquisition of a sufficient area of land for either of these objects, then one of the chemical processes in association with intermittent downward filtration will have the desired effect. By this latter combination a very small area of natural soil, when properly prepared, will perfect that purification which chemical treatment has failed to reach by itself.

"It is much to be regretted that chemists do not base their analyses of water sewage on one fixed quantity of liquid. While some give the proportions in parts per 100,000, and in grains per gallon of 70,000 grains, other chemists give certain ingredients in parts per million."

TEN YEARS' EXPERIENCE

IN

INTERMITTENT FILTRATION.

PUBLIC discussion has been recently renewed on that irrepressible subject, *the disposal of sewage*, which, though frequently described as nasty and offensive, still retains its position as one of the most important problems in the social economy of all countries. That this is the case in England has been most abundantly proved by the facts that the inquiry made in the early part of the present year (1880), into the sewage disposal of the Lower Thames Valley Sewerage District lasted for a period of 45 days, and that no decision acceptable to the Joint Board has yet been arrived at. (December, 1880.)

My motive for publishing the experiences I have gained in Intermittent Filtration, separately and in combination with surface irrigation in the last ten years, arises from no desire to discuss the proceedings of the Lower Thames Valley Main Sewerage Board, but from the conviction that much misapprehension as to the efficacy of land as a purifier of sewage has resulted from the *ex-parte* statements made and the objections expressed at that inquiry, which, though only bearing on the special site unfortunately selected by the Joint Board at East Moulsey, on the Surrey side of the Thames, have been construed by some persons as applicable to the use of land generally. While abstaining from any remarks on the Lower Thames Valley sewage disposal scheme, the fact that other land *at Harmondsworth on the Middlesex side of the river* was selected by three different Engineers—two of whom received premiums of 200 guineas each*—will justify my drawing attention to the circumstance that no land within the Thames Valley, other than that of East Moulsey,

* Mr. James Mansergh and Messrs. Bailey Denton & Co.

was made the subject of investigation, although 300 acres of the land selected at Harmondsworth—the level of which was forty feet higher than that of the Moulsey land, and therefore free from those physical drawbacks with respect to drainage which was made a special ground of opposition—were sold by public auction by Messrs. Baker and Son in the early part of last year (1879) for £20,000—not £70 per acre—a price which if it had been taken into consideration would have shown incontestably that land was to have been obtained on the Middlesex side at a moderate cost, free from those residential considerations which increased so largely the value of and the objections to the selected land on the Surrey side.

With a view to remove as effectually as possible any false impressions that may in consequence prevail, and which may prejudice the interests of Agriculture, I propose to describe in precise terms certain executed works in which Intermittent Filtration is the principal feature, for the accuracy of the details of which I can personally vouch, hoping to prove to the satisfaction of those who may prefer facts to opinions that the particular objections dwelt upon at Kingston, and so often reiterated by Counsel and witnesses at inquiries of the same character—and which must necessarily have some influence on the public mind—are not based on reliable data.

The practice of intermittent downward filtration defined.

In speaking of "Intermittent Filtration," I do not refer to the practice of crowding sewage *continuously* on porous land in the careless manner often adopted to get rid of sewage, and which results in its collection in hollows and low places to injure growing crops—to depreciate the effluent, if there be any—and to cause a nuisance on the surface of the land—(a proceeding which may deserve the term of "intensive irrigation," contemptuously given to intermittent filtration by its detractors,) but I refer to the concentration of sewage *at regulated intervals* on as few acres of land as will absorb and cleanse it without preventing the production of vegetation. It is by this means that the assimilative powers of growing plants are brought to bear on the fertilising elements of the sewage at the same time that the percolation of the sewage through the soil brings it in contact with the atmospheric air prevading the soil, and renders it harmless by oxidation, as explained by the Rivers Pollution Commissioners.*

* In contradistinction to intermittent downward filtration, "surface irrigation" means the distribution of sewage over as many acres as it will wet without supersaturation, having in view a maximum plant growth. To run constantly sewage on to

The particular objections I refer to as those so often repeated by opponents are :— Objections of opponents to the process.

First. That soils become after a time so overloaded with sewage when subjected to intermittent filtration, that their powers of absorption and percolation cease.

Second. That the concentration of sewage for filtration on a small area is attended with greater nuisance than other modes of treatment; and—

Third. That the cost of preparing land for intermittent filtration is so great as to preclude its adoption;—this objection being generally based on the erroneous figures given in the report of Messrs. Rawlinson and Read, the Committee appointed by Mr. Sclater-Booth to inquire into the different modes of treating town sewage.

In the interest both of sanitary science and agricultural progress, it is greatly to be regretted that these objections are so pertinaciously repeated without any real effort being made to arrive at facts. The omission to do so is due perhaps in some measure to the circumstance that the Rivers Pollution Commissioners themselves, when they published the interesting results of the laboratory experiments of Dr. Frankland in 1870, hesitated to recommend the adoption of the process. After declaring that they deduced from the experiments, that "an acre of suitably constituted soil, well and deeply drained, with its surface levelled, and divided into four equal plots, each of which in succession would receive the sewage of six hours, would cleanse the sewage of 3,300 persons," they explained that—

Such a filter was not a mere mechanical contrivance—it was a machine for *oxidising and thus altogether transforming, as well as for merely separating the filth of dirty water.* A field of porous soil irrigated intermittently, virtually performs an act of respiration, copying on an enormous scale the lung action of a breathing animal, for it is alternately receiving and expiring air, and thus dealing as an oxidising agent with the filthy fluid which is trickling through it. To this chemical property must be added another cleansing agency, the actual appetite for certain dissolved impurities in filthy water which soil owes both to general surface attraction, and to the chemical affinities which some of the ingredients possess. The theory of intermittent downward filtration.

A sufficient extent and depth of porous soil having periodical intervals of rest during which the soil drains itself and becomes refilled with air, certainly must be the best possible strainer, oxidiser, and filterer of water, containing nauseous organic impurities both suspended Reason of the River Pollution Commissioners for

gravel or chalk beds, to be soaked in and disappear, as may be seen not far from the Metropolis, is an illustration of "Intensive Irrigation" in its worst shape.

hesitating to recommend the adoption of the process.

and dissolved,—but the adoption of intermittent filtration through land they declared would be open to three formidable objections, viz.: "(1) That it was entirely unremunerative; (2) That the whole of the manure ingredients of the sewage would be absolutely wasted; and (3) That the collection of solid fæcal matters on the surface of the soil with no vegetation to make use of them would probably give rise to a formidable nuisance, especially in hot weather."

It may be remembered by those who have traced the progress of Sewage Disposal, that I had it in my power in the very first work of Intermittent Filtration that was executed in this country—*i.e.*, at Merthyr Tydfil in 1871—to prove that these expectations of the Commissioners were groundless if the operations were modified by the lessons learnt in land-underdrainage. Though my long connection with underdrainage gave me the fullest confidence in the soundness of Dr. Frankland's views, I determined at Merthyr, in the face of the competing processes which were then before the public, to avoid all chance of overcharging the land, and instead of looking to one acre of suitable soil drained 6 feet deep to cleanse the sewage of 3,300 persons, as the Rivers Pollution Commissioners had suggested, to extend the area designed to do this duty to three acres by only applying the sewage of 1,100 persons to an acre, and instead of covering the whole surface of the land so utilised with sewage, which would negative the power of crop production, I determined to distribute it *by furrows*, so as the liquid sewage should reach the roots of the plants growing on the ridges laterally, through the soil without touching their edible parts.

How the anticipations of the Commissioners were met and removed at Merthyr Tydfil.

The result at Merthyr was (and subsequently has been at all other places), that heavier crops of vegetables, giving a better money return, have been grown upon the Intermittent Filtration areas, when cleansing the sewage of 1,100 persons to the acre, than upon surface irrigated land receiving and cleansing the sewage of one-tenth of that population. At Merthyr too (as at other places), the sewage applied being evenly distributed by horizontal furrows, without allowing it to touch the growing crops, has caused no nuisance whatever, nor has any effluvium been recognisable at a distance of 50 yards from the areas.

Thus the three objections anticipated by the Rivers Pollution Commissioners were completely removed. The treatment adopted, instead of being entirely unremunerative, secured in every case large crops of vegetables. No collection of solid fæcal matter took place upon the surface of the ground. The sewage being distributed by furrows of different depths so regulated as to feed the soil with the liquid and

keep back the solid matter in the furrows where it would afterwards be of special value for mixture with the soil, no waste occurs.

Intermittency of application indispensable.

I have quoted the very interesting description given by the Rivers Pollution Commissioners of the principles or theory upon which Intermittent Downward Filtration was based before describing the several illustrations of the practice itself which I am about to give, because it is desirable that it should be previously understood that intermittency of application is a *sine quâ non* even in "suitably constituted soils," whereever complete success is aimed at. No instance of failure can be pointed out where careful underdrainage and careful preparation of surface with proper periods of rest (regulated by the character of the soil), have been adopted, whereas the cases are unfortunately becoming numerous in which defective effluents are discharged from the underdrains, and considerable nuisance created on the surface of the sewaged ground where "intensified irrigation" without regulated periodical application has taken the place of Intermittent Filtration in the true meaning of the term, as explained by the Rivers Pollution Commissioners.

Area of land required in different descriptions of soil.

It is equally desirable to remove from the minds of those who take interest in the subject, any impressions that may exist in consequence of adverse criticism that when I considered it advisable in the first work of the kind (Merthyr Tydfil), to increase the area of land utilised in the proportion of three acres to one acre, there was any intention to discredit the conclusions come to by the Rivers Pollution Commissioners, as to the cleansing capability of "suitably constituted soil." I aimed at such a modification as would certainly ensure success. In every case the extent of surface must necessarily depend (1) on the capability of the upper soil to absorb, and of the subsoil to infiltrate the liquid applied to the surface; and (2) on the depth to which the land may be thoroughly drained in order to provide the necessary bulk of filtering material, and it was not only to remove all doubts on these points but to overcome the disturbing influences due to mixed soils of nominally the same character and the difficulties imposed by nature in keeping down subsoil water, that led me to recommend the increased area.

No arbitrary law applicable to all soils was intended to be laid down at Merthyr. Every day's experience since the execution of that work has served to prove that with the most suitable free soils it is hardly possible to overcharge them with liquid, or to overtax their cleansing

powers, whereas, in the less suitable clayey and peaty soils, the limit of absorptive power is reached before one-fourth of the liquid that would be absorbed by gravelly and sandy land is applied. If we avoid the denser clays as altogether unsuitable (unless they are so altered in their condition by mixing, burning, &c., as to lose their natural character) and regulate the application of the sewage to other soils within the limits of 1,000 persons to the acre of those most suitably constituted, and 250 persons to the acre to those least suitably constituted, all other descriptions of cultivatable land may be made capable of filtration; and the advantage of being able permanently to cleanse the sewage of a district where any land more or less suitable is to be purchased or leased in sufficient quantity to meet these limits, cannot be over-estimated.

When giving the details of the works I am about to describe, I trust I shall be able not only to remove the oft-repeated objections set forth, but to prove that the capability afforded by intermittent filtration, when adopted *separately*, of minimising the quantity of land required, will ensure the purification of sewage at the least cost to the ratepayer; and when systematically adopted *in combination with surface irrigation*, may be made the means of removing the greatest drawbacks experienced by the sewage farmer, and thus afford a tangible benefit to agriculture. Up to this time Agriculture, which it was stated by the highest authorities in Europe, would be immensely advantaged by the use of sewage on land, has realised no gain whatever beyond the benefit of learning what to avoid, and what may be looked forward to when the drawbacks incident to novelty give place to facilities which practice will supply.

Before entering upon these descriptions it may be desirable to explain certain points which have a governing influence in the disposal of sewage when land is resorted to. They may be considered under the following heads:—

I. Character, amount, and value of sewage constituting the outflow of different districts.

II. The quantity and use of solid matters floating in the sewage discharged.

III. The temperature of sewage.

IV. Storm overflows and osier beds.

V. The character of land, more or less suitable.

I. CHARACTER, AMOUNT, AND VALUE OF SEWAGE.

The Rivers Pollution Commissioners showed with remarkable clearness in their report of the 16th February, 1870, that the sewage discharged from towns in which no special trades exist was the same in its distinguishing qualities, and this similarity has been found to exist whether the excrementitious refuse of dwellings be admitted into sewers or whether it be collected separately and removed by the scavenger.

Character of sewage of water-closet towns, and midden towns.

The Commissioners, after giving by numerous analyses the precise constituents of the sewage of water-closet towns and midden towns, stated that these analytical numbers show a remarkable similarity of composition. The proportion of putrescible organic matter in solution in midden towns is but slightly less than in water-closet towns, whilst the organic matter in suspension is somewhat greater in the former than in the latter. They add—

"For agricultural purposes 10 tons of average water-closet sewage may in round numbers be taken to be equal to 12 tons of average privy sewage. The average quantity of chlorine in 100,000 parts of water-closet sewage is 10·66, while in midden sewage it is 11·54. This difference is very significant; it shows that, assuming (which is probably approximately the case) all the urine to reach the sewers in both classes of towns, a larger number of individuals contribute to a given volume of sewage in midden than in water-closet towns. Chlorine, in these cases, represents common salt, and the latter again indicates the proportion of urine in the sewage. The proportion of chlorine, therefore, ought to give the proportion of average individuals (men, women and children) contributing to each kind of sewage; and from this it would follow that the population producing equal volumes of sewage in midden and water-closet towns are as follows:—

In water-closet towns	1,066
In midden towns	1,154

"The cause of this difference in the volume of sewage per head of population in the two classes of towns is obviously to be sought for in the somewhat increased quantity of water needed by and supplied in the former."

As to character of trade liquid refuse.

The liquid refuse from manufacturing works, however, may alter the character and value of sewage, if admitted into sewers, to a great extent. It is therefore essential in designing works for the utilization of sewage on land that the details given by the Rivers Pollution Commissioners of the refuse liquid discharged from trades of different character should be

carefully considered, and that the facts with respect to the trades existing in districts under treatment should be ascertained with precision.

Rivers Pollution Prevention Act, 1876, Section 7, to be considered.

By the wording of the 7th section of the "Rivers Pollution Prevention Act, 1876," it will be seen that the Legislature contemplated the admission of trade liquids into sewers as far as possible, for it is declared that—

"Every Sanitary or other Local Authority having sewers under their control shall give facilities for enabling manufacturers within their district to carry the liquid proceeding from their factories or manufacturing processes into such sewers, provided that this section shall not extend to compel any Sanitary or other Local Authority to admit into their sewers any liquid which would prejudicially affect such sewers or the disposal by sale, application to land, or otherwise of the sewage matter conveyed along such sewers, or which would from its temperature or otherwise be injurious in a sanitary point of view."

As to quantity of trade liquid.

It is therefore some satisfaction to know from the experience already gained that the ingredients used in trade when dissolved and mixed with sewage do not always injuriously affect vegetation. Some are found to be harmless and others beneficial. The quantity of water used in some trades, however, is so great as to be alone prohibitory to its admission into sewers, for instances are not rare in which as much water is used in a single mill as that consumed in a moderately sized town.

Of subsoil water admitted into sewers.

Sewage proper.

The quantity of sewage forming the constant discharge from the sewers of any district depends very greatly upon the amount of dilution to which the "sewage proper" is subject by mixture with *subsoil water*, and the amount necessarily affects in the highest degree the mode of sewage-proper disposal. The "sewage proper" of a district consists simply of the water supply made filthy by use when passing through habitations. It frequently happens that this is more than doubled by the water finding its way into the sewers from the ground in which they are laid. One of the greatest difficulties, in fact, with which an engineer has to contend is the existence of subsoil water, inasmuch as any joints which are not water-tight not only admit the subsoil water into the sewers to dilute the sewage, but they allow the sewage which should be confined to the sewer to escape under pressure into the surrounding soil through the same interstices that would admit the subsoil water. Sewers should therefore be invariably made watertight, and where underground water stands sufficiently near the surface to cause injury to the health of the locality it should be lowered by independent subsoil drains. All sewers jointed with clay are particularly subject to much variation of outflow. Nothing in truth has led more directly to unsatisfactory results than the use of

clay for jointing under the pretence of economy, for in wet soils the sewage-proper has from such causes been doubled and trebled in quantity, while under other influences the discharge from the sewers has been so much reduced as entirely to defeat good management.

Of surface waters admitted into sewers.

It is now generally conceded by sanitary engineers that surface waters should be excluded as far as practicable from public sewers, and that a separate system of surface-water drains should exist in all towns to take the rainfall to the natural streams of the watershed. Objection has been raised, however, to the exclusion of surface waters, on the ground that the sewers are not then so thoroughly flushed as when provision is made for the admission of the rainfall. Experience, however, has shown that, where separate systems are carried out, there still exists a considerable influx of rain water from the back roofs of buildings and from other impervious surfaces connected with dwellings, the off-flow from which cannot practically be excluded from the private sewers communicating with the public ones, which affords ample means of flushing the sewers in times of rainfall, without the addition of surface waters from public roads, front roofs, &c. Where separate systems do exist, and the necessary storm overflows are provided, the discharge from the sewers will still be found, in wet weather, to occasion great derangement. To meet this difficulty Osier Beds are provided in connection with Intermittent Filtration areas, through which the excess passes, and by which it is freed from solid floating matter before reaching the natural outfall. It is only in this supplemental way that Osier Beds can be safely used.

Osier Beds.

Value of sewage.

The last ten years have taught us that the value first put upon liquid sewage by Chemists (from 1*d.* to 2½*d.* per ton), though arrived at by the most careful analysis and computations, is quite irreconcilable with tangible results. The country was, indeed, led to expect that the sewage of 20 persons might be sufficient to produce heavy crops, and at the same time maintain the fertility of an acre of land, whilst the estimate, which gained general favour was, that with systematic distribution, the sewage of 100 persons to the acre would be attended with certain profit! At the same time the value of the solid materials existing in sewage was even more exaggerated by patentees and other persons.

Value of Sludge.

Instead of liquid sewage being worth even a penny a ton, and the solid materials worth £3 a ton, as it was often asserted had been realised, we find, as will be shown when treating of sewage farming, that the utmost price given for the former has not reached one-third of a

farthing a ton, while Dr. Voelcker, F.R.S., the Consulting Chemist of the Royal Agricultural Society, has incontestably shown that the money value of the dried sewage—"sludge"—offered for sale after treatment at Bolton, Bradford, and Leeds varies from £1 1*s.* 1*d.* to 16*s.* 8½*d.* a ton, and is often unsaleable at any price.

The report of Messrs. Rawlinson and Read, the Committee appointed by the late President of the Local Government Board, contained the valuable report of Dr. Voelcker, setting forth these figures. It exposed with singular force the almost worthless character of sludge when separated from sewage liquid. In order to ascertain the value of the fertilising properties of sewage and excreta, and also of the manures manufactured therefrom, and of their commercial value to the farmer, the Committee collected samples at Bolton, Bradford, Leeds, Coventry, Rochdale, and Halifax, and caused them to be analysed, and the following is the report referred to:—

Dr. Voelcker's Report on the value of sewage as a manure.

"*On the Fertilising and Commercial Value of Sewage and Night-soil Manures.*—The fertilising and commercial value of sewage-sludge and of portable manures prepared from sewage, night-soil manures, and of common farm-yard manure, chiefly depends upon the proportions of phosphate of lime, potash, and nitrogen which these fertilisers contain.

"These fertilising constituents of manures can be bought at the present time in the form of concentrated artificial manures, such as guano, bone dust, sulphate of ammonia, &c., at the following rates:—

Phosphate of lime at	1*d.* per lb.
Potash at	2*d.* ,,
Nitrogen calculated as ammonia at	8*d.* ,,

I need hardly say that in such concentrated forms, phosphate of lime, potash, and ammonia have a much greater value than they possess in the shape of manures, the bulk of which mainly consists of materials without value, and occurring in abundance in almost every kind of soil.

"I would, however, direct attention to the fact that according to my own experience and that of others, sewage manures, night-soil manures, and ordinary farm-yard manure contain but little ready-formed ammonia, and that by far the largest proportion of the nitrogen in these manures occurs in them in the shape of nitrogenous organic matters in which form nitrogen is less efficacious, and in consequence less valuable, than in the form of ready-formed ammonia or salts of ammonia.

"In estimating the theoretical value of manures, the nitrogen is generally assumed to be present in sewage and similar bulky manures in the form of ammonia, or, at all events, to have the same value as the nitrogen in the salts of ammonia. This, in my opinion, is a mistake, and the nitrogenous constituents of sewage manures are valued at too high a rate if their nitrogen is calculated into ammonia, and 8*d.* allowed for each pound of the calculated amount of ammonia. In order to avoid the charge of having put too low an estimate upon the fertilising constituents of

sewage-manures, I have allowed in the estimate 8*d.* per pound for the calculated amount of ammonia which the nitrogenous matters in a ton of manure are capable of gradually producing under the most favourable circumstances on their final decomposition.

"The following Tabular Statement shows at a glance the theoretical or calculated money value of the different sewage manures which were submitted to me for analysis:—

"Theoretical or estimated Money Value of one Ton of the treated Sewage Sludge.

	£	*s.*	*d.*
(1.) Bolton sludge—from the M. and C. sewage process*	0	9	8½
(2.) The same dried, leaving 15 per cent. of moisture in the sludge	1	1	1
(3.) Solids drained from sewage before the liming process at Bradford	0	11	0½
(4.) The same with 15 per cent. of moisture ...	0	19	3
(5.) Bradford Corporation Sewage Outfall Works, sludge from drying pits, no artificial heat being used	0	4	8
(6.) The same with 15 per cent. of moisture ...	1	0	0½
(7.) Deposit from the sewage of Leeds treated by the A B C process	0	8	4½
(8.) The same with 15 per cent. of moisture ...	0	16	8½
(9.) Manure produced by the General Sewage Manure Company at Coventry	0	16	9½
(10.) Rochdale Manure	0	15	11½
(11.) Manure manufactured by the Goux Company at Halifax	0	17	7

"According to the most reliable statements the separation of the suspended matters of sewage by precipitation and filtration, and the production of one ton of dried sewage deposits, apart from the costs of the precipitation agents which are used, entails an expense of about 30*s.* for each ton of portable dried sewage manure. It is evident, therefore, that the cost of manufacture considerably exceeds the theoretical or calculated money value of every one of the sewage deposit manures, the composition of which is given in the results of analysis in Appendices Nos. 1, 2, and 3. The estimated money value of sewage and night-soil manures, as has been stated already, does not fairly represent their real commercial value. The bulk of all the samples submitted to me for analysis consists of matters which occur in abundance in almost all soils, and which at any rate have no commercial value, or rather have a negative value, inasmuch as carriage has to be paid for them, and the application of bulky manures necessarily is more expensive than that of concentrated manures, such as guano or bone dust. It is, therefore, manifestly practically wrong to estimate the money value of such bulky and poor manures by the same standard of prices at which the commer-

* M. and C. are the initials of the patentees. The ingredients used are lime, carbon, house ashes, soda, and per-chloride of iron.

cial value of guano, bone dust, sulphate of ammonia, and similar concentrated artificial manures are estimated. A more rational and correct estimate of the true value of sewage and night-soil manures is obtained by comparing them with ordinary farm-yard manure, and the price which is paid for the latter.

"Good farm-yard manure, I find, contains on an average in the ton 6½ lbs. of soluble phosphate of lime, 8½ lbs. of insoluble phosphate of lime, 13 lbs. of potash, and nitrogen equal to 17½ lbs. of ammonia.

"By allowing for soluble phosphate of lime *2d.* per lb., the same price for potash, *1d.* per lb. for insoluble phosphate of lime, and *8d.* per lb. for ammonia, the calculated money value of a ton of farm-yard manure amounts to *15s.* *7½d.*, as will be seen from the following figures:—

	s.	*d.*
6½ lb. of soluble phosphate of lime, worth at *2d.* per lb.	1	1
8½ „ insoluble „ „ *1d.* „	0	8½
13 „ potash ... ... „ *2d.* „	2	2
Nitrogen, equal to 17½ lbs. of ammonia, calculating ammonia at *8d.* per lb.	11	8
Total calculated money value of a ton of farm-yard manure	15	7½

"It thus appears that if we estimate the money value of good farm-yard manure, according to the same rules at which the principal fertilising constituents in the dung can be bought in concentrated manures, one ton of farm-yard manure would be worth in round numbers *15s.* However, good dung can be bought in many places at *5s.* per ton, or one-third its estimated money value, and practically the highest price which a farmer can afford to pay for good dung, if he has to cart it even a few miles, would not exceed *7s. 6d.* per ton, one-half its estimated money value. The difference between the estimated money value of farm-yard manure (calculated at the market rate of the constituents when sold as concentrated artificial manures) and the actual market price may be fairly taken to represent the difference in practical value caused by the greater expense of the carriage and application of farm-yard manure, and the less vigorous action of organic nitrogenous compounds as compared with ammonia salts.

"In estimating the commercial value of sewage and night-soil manure the calculated value of which does not exceed £1 *1s.* per ton, precisely the same circumstances have to be taken into account which affect so largely the market value of ordinary farm-yard manure. Accordingly the price which the farmer can afford to pay for the sewage and night-soil manures, analysed by me, or their real money value, will be only from one-third to one-half that of the calculated estimates given on the basis of their analyses.

"The following Table shows the market price or real money value of the various sewage and night-soil manures, samples of which were submitted to me for analysis.

"Practical or Market Value of one Ton of the treated Sludge.

	s.	d.		s.	d.
(1.) Bolton sludge from the M. and C. sewage process	3	3	to	4	10
(2.) The same sludge, 15 per cent. of moisture	7	0	„	10	6
(3.) Solids drained from sewage before the liming process at Bradford ...	3	8	„	5	6
(4.) The same with 15 per cent. of moisture	6	5	„	9	6
(5.) Bradford Corporation Sewage Outfall Works, sludge from drying pits without artificial heat	1	6	„	2	4
(6.) The same dried with 15 per cent. of moisture	6	8	„	10	0
(7.) Deposit from the sewage of Leeds treated by the A B C process ...	2	9	„	4	2
(8.) The same sludge with 15 per cent. of moisture	5	6	„	8	4
(9.) Manure produced by the General Sewage Manure Company at Coventry	5	6	„	8	4
(10.) Rochdale manure...	5	4	„	8	0
(11.) Manure manufacture by the Goux Company at Halifax	5	10	„	8	9

"In my judgment this tabular statement fairly represents the money value of eleven different samples sent to me for analysis at the place where the manures were produced.

"Some of the products are worth a good deal less than an equal weight of common dung, which fully explains the circumstances that most sewage manures find no ready sale even at a low price, and that in many works such manures accumulate to an inconvenient extent.

"Indeed, comparatively few farmers are so situated that they can afford the expense of carting semi-dried sewage sludge, containing from 60 to 70 per cent. of moisture, from the works to their fields. The refusal to accept such sludge as a gift in not a few instances rather shows sound discrimination than ignorance on the part of the farmers.

"(Signed) AUGUSTUS VOELCKER."

Other uses of liquid sewage.

Liquid sewage will be found to have a value as an effluent which has not yet been reduced to figures nor considered by sanitary authorities. From the experience gained at Merthyr, Kendal, Abingdon, Malvern, Halstead, and other places, some of which may be characterised as manufacturing towns, it may be assumed with certainty that by Intermittent Filtration through "suitably constituted soil," some descriptions of liquid trade refuse may be purified at the rate of at least 100,000 gallons to an acre of land, and brought to a condition

that will make the effluent capable of re-use for trade purposes. Indeed, the practice of Herr von Rath of Silesia, of concentrating the underdrainage water of the land to which the foul liquid of his factory had been applied, and then raising it for re-use, may in many cases be favourably adopted in the busy northern valleys of this country, and there is no doubt that at some future period we shall find that in districts where mills using large quantities of water are congregated, a combined treatment of trade liquids will be adopted, in which this view of the subject will prevail.

Sewage effluent water used for trade purposes.

I cannot do better than reprint a translation of a letter I received from Baron von Liebig, very shortly before his death. He said:

"Receive my best thanks for your letter of the 3rd inst., and for the paper on Intermittent Filtration through natural soil. I have read this with great pleasure and real satisfaction. . . . Your plan for the purification of liquid sewage, and the removal of its injurious qualities, as well as the technical execution of the plan, and the use of sewage as manure, are alike excellent, and I only wish that it may be made use of in other places. In Silesia, for some years past, the best use has been made of your principles in the Beet-root Sugar Manufactory of Herr von Rath. In the neighbourhood where this manufactory is situated there is a want of spring-water, and of water generally, and this want has called forth the following arrangement:—All water that has been used in the manufactory, and generally all waste or foul liquids, are discharged on to a well drained piece of land close at hand, and the filtered effluent water is collected in a well. It is pure and clear, and it is again raised by a pump, and used in the manufactory as fresh water."

Use and value of sewage liquid for watering.

This is a good practical illustration of the use of sewage water when purified; and there is every probability that the power of so utilising *effluent water* may be realised at Dewsbury, where the sewage, after passing through the filter beds laid out to cleanse it, may be seen flowing into the Calder, cleaner than the river water itself. But there is another use, which, though acknowledged generally to be of value, has been so mixed up with the practice of Surface Irrigation as to lose its speciality. There are times in the year when all farmers would value highly the acquisition of *water* (apart from manure) to invigorate their growing crops, and it is one of the objects of this treatise to show that by a proper arrangement for distribution the use of sewage for watering may have its place. A farmer in a dry year would pay more for a timely *watering* with sewage than he would for any quantity of liquid manure in a wet one.

II. THE QUANTITY AND USE OF THE SOLID MATTERS FLOATING IN SEWAGE.

Character and quantity of solid ingredients of sewage.

The quantity of the solid portions present in sewage varies considerably, and it is increased in proportion as trade refuse is admitted into the sewers. The floating ingredients exist in three gradations of weight and size.

In the first are included the bulky substances which would interfere with the valves of pumps if the sewage were raised, and would be offensive and obstructive to plant growth if distributed on the surface of land. They consist of almost every imaginable thing that could be thrown into a sewer, and they are generally arrested and extracted by screening. Not being of any large aggregate quantity they are readily removed when screened out of the sewage.

Heavier portions.

Road detritus.

In the solids of the second gradation are included the smaller but heavy substances which, after passing through a screen, quickly sink by their weight to the bottom of any tank or receptacle while the sewage is in motion. They include road detritus or sand, which being valuable in itself may be separated from the lighter substances by mechanical deposition and utilised.

Sludge.

The suspended substances of the third gradation, frequently called "sludge," comprise the organic matter and those minute inorganic substances, including very fine sand, which float onwards and deposit themselves very slowly even when the containing liquid is in a quiescent state. When the sewage is in motion the precipitation of these minute substances can only be readily effected by mixture with certain chemicals.

At Birmingham, where the outflow of sewage is about 12,000,000 gallons daily in dry weather, and lime has been used as a precipitant mixed with the sewage at the rate of 23¼ cwt. per million gallons, the road detritus and sludge, together with the lime, amount, on an average, we are told, to about 360 cubic yards daily. Such, however, is the worthless character of the "sludge" that no one will take it away at a gift, and it is therefore dug into land forming part of the Saltley Farm and buried out of sight, at the cost of £12 per acre.

Of sludge alone the quantity would seldom exceed 100 grains per

gallon, and it is the existence of this material in combination with more or less road detritus that has been made an objection to the use of land for the cleansing of sewage by representing it as "clogging" its pores.

If properly distributed on carefully prepared surfaces sludge on land generally does good rather than harm; in fact, it only has an objectionable effect when it is mixed with particular trade refuse. Dispassionate inquiry would satisfy all persons that the difficulties stated to exist on account of sludge are imaginary. Harm sometimes occurs in surface irrigation when the quantity of solid matter is large,—such as is occasionally the case when storms wash out the sewers after accumulation of solid matters during drought,—and when it is allowed to settle in hollows on the surface of carelessly formed land to kill growing vegetation, and, possibly, to give off effluvium. Injury to vegetation is most likely to occur, under such circumstances, when solid trade refuse is admitted into sewers.

As the opinion now generally prevails that artificial treatments of sewage are only admissible when land cannot be obtained, it should be known that experience has shown that "sludge" is not a bar to the application of sewage to land. It is only necessary to remember that "sludge" consists of vegetable and animal substances which are perishable, mixed with earthy and mineral substances in very small particles which are not perishable, to realise the fact that they cannot possibly clog land when dry. The most minute particles consist of fine road sand which float on in the liquid after the heavier detritus has deposited itself. When these perishable and imperishable substances find their way into the interstices of the soil they must each, from their nature, obviously add to its porosity, inasmuch as the perishable substances leave open spaces as they decay, whilst the imperishable substances from their gritty nature necessarily help to increase its filtering capability. So long as the sludge is wet it impedes absorption to a certain extent, but when once dried and the land broken up by the plough, the scarifier, or the spade, it not only ceases to uphold the liquid, but naturally and permanently helps to let it into and through the soil.

In Intermittent Downward Filtration, the deposit of the sludge takes place in the furrows, which form an essential feature in the system, and we find in practice that when first used the furrows themselves absorb the sewage too quickly, but that as the deposit of sludge accumulates in them they resist infiltration and the sewage is driven into the ridges

on each side and so distributes itself more equally than if the furrows alone absorbed it. As soon as the deposit of sludge on the sides of the furrows is sufficient to prevent infiltration in any great degree, the sewage is withheld from the areas so affected. The sludge is then allowed to dry (partially) in the furrows, and when in a fit condition it is lifted and dug into the ridges,—as can be seen practised at Gennevilliers (Paris). The slimy matter which had appeared so considerable, and which puddled the bottom of the furrows, when in a wet state, shrinks to a skin of very insignificant thickness when dry, and is readily broken up and mixed with the soil.

Sludge beneficial to land.

Experience has shown that sludge (with such fertilising ingredients as it contains) cannot be more cheaply conveyed to places where it would be beneficial than by the liquid sewage itself. The very trifling value of the suspended ingredients renders it all the more desirable that they should be disposed of by the same means and at the same time as the liquid.

The objection raised to the distribution of sewage, containing solid ingredients in suspension amongst growing plants because the solid matters will cling to their stalks and leaves, vanishes altogether when furrows are made the channels of distribution, and when no more sewage is distributed on the surface of land than the land will absorb and vegetation requires. It is only when the pernicious practice of flooding land is resorted to that sewage will rise up among the stalks and leaves growing upon it. At Gennevilliers the sewage never touches the vegetation growing in the irrigated ground. It is distributed throughout the entire breadth of the plains *in furrows* in precisely the same way as in Intermittent Filtration designedly practised as such in this country.

Objection to the distribution of solid matters among growing vegetation.

III. THE TEMPERATURE OF SEWAGE.

An objection is often raised, that frost acts as a bar to the distribution of sewage on the surface of land in the winter seasons. Mr. William Haywood, the Engineer to the City of London, having carefully ascertained the temperature of the internal air of sewers, and compared it with that of the external air for a whole year, found the mean winter temperature of the former to be 11·61 degrees higher than the latter. In summer the sewer air was 3·12 degrees colder than the outer air.

Temperature of sewage.

The following Table gives the comparative figures :—

Time of Year.	Temperature in external atmosphere in shade.			Temperature in sewer.		
	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.
	°	°	°	°	°	°
Summer	72	55	65·04	68	56	61·92
Winter	34	30	32·37	52	40	43·98
Spring	61	46	52·46	59	48	52·52
Autumn	68	48	59·90	70	53	62·97
Average of the whole year	...	...	50·24	...	...	55·35

The Sewage Committee of the British Association ascertained at Merthyr that on the coldest day during the time the observations were made, the difference between the *temperature of the sewage* delivered to the filtration areas, and that of the air was 8 degrees, while the temperature of the effluent water discharged from the underdrains was found to be 1 degree higher than sewage itself. The observations here given were made for eight days in January, and in July, 1872. They were recorded as follows :—

Date.	Temperature.				Date.	Temperature.			
	At Noon.		Average during day.			At Noon.		Average during day.	
	Air.	Ground.	Sewage.	Effluent water.		Air	Ground.	Sewage.	Effluent water.
1872.	°F.	°F.	°F.	°F.	1872.	°F.	°F.	°F.	°F.
Jan. 9 ...	...	...	49	46	July 2	70	63	60	56
,, 10 ...	50	49	49	46	,, 3	70	64	60	55
,, 11 ...	49	48	50	47	,, 4	75	73	60	55
,, 12 ...	48	46	48½	45	,, 5	69	70	60	56
,, 13 ...	49	47	47	45½	,, 6	68	70	55	68
,, 14 ...	50	49	48	46	,, 7	68	64	60	55
,, 15 ...	40	38	43	45½	,, 8	68	44	60	55
,, 16 ...	37	39	45	46	,, 9	68	50	60	55

These and the previous figures prove that the distribution of sewage on land is not likely to be much impeded by frost, and that when collected in furrows, as is the case in Intermittent Downward Filtration, the sewage will thaw the frozen condition of land with which it may be brought in contact. This is found to be particularly the case where the sewage is distributed by furrows in contradistinction to surface spreading. Frost.

The Rivers Pollution Commissioners in their examination of the effluent water from the Croydon Sewage Farm, on the surface of which the sewage is spread by wide irrigation, found that during frost in winter it was slightly, but only slightly, less pure than at other times.

IV. STORM OVERFLOWS.

The outlets called storm overflows cannot be done without; they are the safety valves essential to all systems of sewerage and sewage disposal. It is not sufficient, however, to declare that when the sewers of towns are overcharged by the dilution due to rainfall they should come into operation as a matter of course. It is true that the volume of rivers is at such times also increased by the off-flow from tributary ground surfaces and that their waters cannot be made much worse than they then are. Nevertheless there must be a limit to the frequency with which rivers may be thus occasionally polluted. Storm overflows.

Experience has not afforded any clue to that limit beyond establishing the fact that no mode of cleansing sewage by tank treatment or by irrigation over, or filtration through land, can be effective when the sewage is diluted by rainfall beyond a certain amount. One inch of rain thrown off 100 acres equals 2,262,200 gallons, and if one-tenth of this quantity suddenly reaches the outfall—say, in half an hour—no mode of treatment yet devised can deal with such a quantity without injury or defect. It is easy enough to deal with an outflow from sewers if the quantity be constant and is ascertained, but it is quite beyond the powers of any engineer to devise a means of treating liquids swollen by sudden and extraordinary dilution. If therefore the law refuses to recognise storm overflows from sewers because when called into action they cause some pollution, no national advantage would be gained, inasmuch as the incapability of cleansing sewage when swollen to the extent mentioned

would involve an overflow of an equally injurious character from the land or works intended in ordinary times to cleanse it.

Osier beds for the cleansing of storm waters.

Osier Beds may be usefully connected with Storm Overflows wherever the latter are necessary on Sewage Farms to discharge such waters as are suddenly thrown down upon them in excess of what the land has been intended to absorb. Several instances of this use of Osier Beds will be found in the following pages, but it should be clearly understood that they are not here proposed to do the service suggested in the Official Report already referred to in which it is stated that—

"A portion of each farm should be specially deep-drained and prepared for land-filtering the sewage during the winter and wet weather. When these filters," it is said, "are laid out in ridged beds, some roots and vegetables can be raised with success, as the sewage generally flows down the channels. But in times of floods and storms *the sewage may rise above the beds*, so that perhaps osiers, which would not be damaged by being flooded for days, would be the safest and therefore the most profitable crops to grow upon them."

These words must have been inadvertently published, for it is hardly possible that the authors of the Report could really have supposed that filtration areas when growing roots and vegetables on ridges were liable, under proper management, to be flooded, or that underdrains, which are positively essential to filtration, would resist the ingrowth of Osier roots, which have a singular aptitude for filling undergrains, whatever may be their depth. Filtration areas, properly constructed, are less subject to floods than other land designed for the reception of sewage, and the surest way of rendering them useless would be to plant osiers over the underdrains to fill them with their roots. Underdrains should be kept free of all possible obstruction.

Osier Beds, to be useful, on Sewage Farms, should be connected with Storm Overflows, so that excesses may run through them. The beds are formed in horizontal areas which serve to *check* the rapidity of flow of suddenly discharged rainfall. This check causes the deposit of the floating solid matters in the furrows, while the flood-water rises and overflows the ridges and the osiers growing on them. These beds are not underdrained in any way; their simple purpose being to clarify those excess-waters which without the check afforded by them would be impetuously discharged, together with everything floating in them, into the natural streams of the watershed.

V. THE CHARACTER OF LAND MORE OR LESS SUITABLE FOR SEWAGE CLEANSING.

Speaking generally, the greater the natural fertility of land the more suitable it is for Surface Irrigation, inasmuch as the stimulation of plant growth, resulting from a covering of liquid, can only be maintained under varying conditions by natural productive power. This is evidenced on every Sewage Farm, even after it has been irrigated for years, by the superior growth of crop on one part compared with another receiving the same quantity of sewage. Poor land can be made productive slowly by the process of irrigation, but it is found that the best return from a given outlay is gained from a soil naturally fertile.

Suitable and unsuitable soils.

The most suitable soil for both Irrigation and Filtration is a sandy loam with a small proportion of gritty gravel to quicken percolation. The soils most unsuitable are very dense clays, bog peat, and very coarse gravels. All soils which absorb and retain water, and which are therefore subject to expansion as they receive, and contraction as they part with it, will crack, and any liquid applied to the surface will descend by the cracks as far as they reach. In stiff clays these cracks extend to the drains and the liquid poured on the surface will pass away by the drains to the rivers and streams in a condition almost as foul as when it was applied.

Loams.

Loams with a small portion of clay are not subject to the same drawback if the surface soil is mixed with burnt earth and is deeply cultivated. The superior properties of loamy land, properly drained, consist in the affinity for ammonia which its clay constituents possess, and the extreme comminution to which it is reducible by the action of air and water. Under proper treatment a loamy soil becomes, not only more productive of vegetation, and therefore a better purifier of sewage, but it constitutes a better filtering material (mechanical) than either gravel or coarse sand.

Clay soils.

Clay soils are not to be recommended for Surface Irrigation, and can only be used for Filtration by an outlay in draining, earth burning and mixing, which Sanitary Authorities are indisposed to expend.

The best soils for Intermittent Filtration are those of a free character closely pulverised with such a proportion of alumina equally dispersed through their bulk as does not exceed 7 per cent. of their con-

stituents. Sewage will pass but slowly through such description of soil, and they therefore require quickening by carefully designed underdrainage to overcome their natural retentiveness. Soils of this description will probably contain from 80 to 90 per cent. of insoluble silicates and sand by the chemist's analysis.

Absorptive and retentive powers.

The capacity of soils to absorb water is no criterion whatever of their cleansing capability, whilst their *retentive* powers exercise great influence on the rate of percolation and the quality of the effluent. A coarse gravelly soil thoroughly drained, for instance, will absorb and discharge liquid almost as quickly as it reaches its surface and will give out an effluent but imperfectly purified, whereas a loamy soil, having a sufficient proportion of sand to render it free and to fill it with close interstitial spaces for aëration, will discharge a satisfactory quantity of purified water by the underdrains and maintain a very superior effluent.

Experience conclusively shows that while some soils, even in their natural unmoved condition, will let sewage pass through them too quickly, others have retentive powers—I speak of clay and peat soils—which not only retard in an unfavourable degree the passage of water through them, but in some degree injuriously affect the effluent itself by rendering it cloudy or discoloured, though not chemically objectionable.

The effect of pouring liquid on soils when charged by attraction is to drive out by the fresh liquid that which is already in possession of their interstitial spaces, and as these spaces can hardly be said to be perfectly aërated (though it can only be by the influence of the atmosphere existing in the soil that the water is driven out), the action is not as perfect as desirable. A peaty soil is the most retentive and at the same time the most absorbent of soils. It will hold water of greater weight than itself, but it readily yields when in this saturated condition to the gravitating force of liquids applied to the surface. Clays of the denser nature—such as the London Clay *in situ*, the Stiff Clay Beds of the New Red Sandstone, and the Boulder Clay overlying the Oxford Clay, and others absorbing water weighing as much as one-third to one-half of their own weight, according to their undisturbed or broken condition—will stubbornly resist its passage through them. It is this condition that renders them the most unsuitable of all soils for filtration, though by burning and mixing they may be rendered available at a cost which though comparatively great may yet be less than that of other treatments.

Closely related to the absorptive and retentive powers of soils is their evaporating property, the effect of which at certain times of the year is so great that in cases where there is no subsoil water to dilute the effluent, the quantity discharged has been less than half the quantity of the sewage distributed over the surface. I make this statement having heard it often observed that the measure of the effluent in such cases will accord with the quantity of sewage cleansed. Evaporation.

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1. MERTHYR TYDFIL, SOUTH WALES.

Commencing the instances I desire to describe with that of Merthyr Tydfil, which has been so ingeniously misrepresented in Counsels' speeches, witnesses' evidence, published papers, and official reports, I trust to free the matter of much of the doubt with which it has been surrounded, by the relation of facts that have been established and which are still to be studied with advantage. They will fully establish both the soundness of Dr. Frankland's theory of Intermittent Downward Filtration, as expressed in the report of the Rivers Pollution Commissioners, and the success of the works founded on that theory, which were carried out at Troedyrhiew on my report to the Lords Justices of Appeal in the following year (1871) at some risk to my reputation as a practical man, in consequence of the hesitation to recommend its adoption manifested by the Commissioners themselves.

As early as April, 1869, Mr. Samuel Harpur, the Local Surveyor of the district, proposed to the Local Board a scheme which they approved for utilising the sewage of the district by surface irrigation. The land intended to be taken consisted of 375 acres in the valley of the Taff; of which one block, containing about 75 acres, was situated at Troedyrhiew within a quarter of mile of the village of that name, and about two miles from Merthyr Tydfil, and the remaining 300 acres, eight or ten miles lower down the valley, and to which the sewage was to be conducted by an outfall sewer of a very costly character. It was in consequence of the heavy character of the irrigation works and outfall sewer, and the time which would be taken to perfect them, that proceedings in Chancery were taken by certain riparian owners who desired that the pollution of the River under which they suffered should be prevented Works originally intended by Local Board. Proceedings in Chancery.

during construction, and the appearance of the writer on the scene was in consequence of his being appointed by the Lords Justices to effect the remedy. The treatment suggested for this temporary relief was Intermittent Downward Filtration as propounded by the Rivers Pollution Commissioners. The writer selected for this purpose 20 acres of the free soil, of which he found the 75 acres at Troedyrhiew to consist.

Interim remedy adopted.

The population of the Merthyr district was stated, in 1871, to be about 50,000, of which the sewage equivalent to that from 25,000 persons found its way into the sewers discharging at Troedyrhiew. The total dry weather outflow at the same date varied from 700,000 to upwards of 1,000,000 gallons daily, increased in wet weather to 2,000,000 gallons.

The selected 20 acres were divided into four areas of five acres each, which it was intended should be drained seven feet deep, but which depth, owing to the work being imperfectly done, was not quite gained. The mean depth, however, gave two cubic yards of drained, but not necessarily perfectly aërated, soil for every square yard of surface. Thus every plot of five acres contained 48,400 cubic yards of filtering material.

To convey the sewage of Merthyr from the tanks which then existed to this land (the 20 acres) involved the construction of a delivering conduit of considerable length, available also for the remaining 55 acres of land forming the Troedyrhiew Farm. The drainage of the land and the preparation of the surface were undertaken by a contractor not specially acquainted with land operations, and were therefore so unsuitably executed in the first instance that, upon complaints being made, the writer was called upon by the Lords Justices to take the work under his own immediate supervision and to rectify and complete it. It need hardly be said that a long length of delivery conduit designed for the service of the whole farm of 75 acres and the re-execution of a considerable part of the drainage and levelling increased considerably the cost of the works of preparation;—and that the amount should hardly have been charged against the 20 acres only. Reference is made to this because the large outlay involved has been published, and is often quoted by opponents as a reason why Intermittent Downward Filtration should be avoided. It is, consequently, necessary in the interests of sanitary science that the facts should be known, particularly as from some inexplicable cause no opportunity was given the writer by Messrs. Rawlinson and Read of explaining the facts when

Cost of interim works misrepresented.

in the course of their inquiry into the several modes of treating town sewage they visited Merthyr, and having obtained certain figures, sent them forth to the public without stating the attendant circumstances.

Effluent analysed.

For five months the sewage, equivalent to that of 25,000 persons, was put on the 20 acres, and it was so effectually cleansed, that when Dr. Frankland analysed the effluent on the 20th of October, 1871, the amount of organic nitrogen was found to be ·012, and the amount of ammonia ·025, of one part in 100,000 parts. In 1872 the same eminent chemist, confirmed by Drs. Benjamin Paul and Russell, found the amount of organic nitrogen to vary from ·014 to ·033, and the ammonia from ·060 to ·095. *See Standards previously given.*

The Troedyrhiew Farm amply sufficient of itself for Merthyr alone.

The filtration areas, though laid out as a temporary expedient, did their work so completely that it soon became apparent that if the whole of the comparatively small farm of Troedyrhiew (75 acres) had been properly prepared it would have been ample in itself to have cleansed the whole sewage of Merthyr for the next 30 years without recourse to the 300 acres of distant land.*

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* *Extract from Evidence given by Mr. Harpur, before the Rivers Pollution Commissioners, in* 1872.

Q. What do you suppose to be the population draining out of your exit (at Troedyrhiew), what number of people? *A.* The number of people directly connected with the sewers is about 20,000, but they are increasing now, and we are just extending the drains.—*Q.* As regards the drainage from the other 30,000 or 40,000, what proportion of their drainage, under this unconnected system, also finds its way into the exit? *A.* As far as the bulk or quantity of drainage goes, I believe it will be found, when the drains are connected, that the increase will be comparatively slight.—*Q.* What proportion of the personal waste of this unconnected population at present finds its way into the sewers, do you suppose; I mean of the excrementitious matters? *A.* I daresay a third of the excrementitious matters of the population not connected directly with the drains gets into the sewers.—*Q.* The excrementitious matter from 30,000 people? *A.* Yes.—*Q.* Do you agree with Mr. Bailey-Denton, in supposing that the filtration works below Troedyrhiew are incapable of dealing with more than one-third of additional inhabitants? *A.* I do not agree with that, I do not think that Mr. Bailey-Denton puts it as a matter of course, but he merely gives that to keep himself within safe limits.—*Q.* How much additional waste do you think the whole of the land is capable of defecating? *A.* I do not think we can suppose that the 20 acres and the 50 acres are capable of taking more than they are taking now, I think they are sufficiently sewaged.—*Q.* You mean sufficiently in the interest of the crops? *A.* Yes.—*Q.* Did you notice when the whole of the sewage was being passed on to the 20 acres, any tendency for the land to choke up? *A.* No. —*Q.* You have said that you thought the 20 acres would not cleanse much more than

In fact it is certain that had not the notice of purchase been already served on the Landowners, and the works themselves commenced, the Local Board of Merthyr would, as soon as the effect of the filtration works was seen, have limited their operations to the Troedyrhiew Farm alone.

That I am justified in stating this will appear from the following figures:—

The effect on the ratepayers of Merthyr.

From the best information I can collect, I am led to believe that the actual outlay in preparing the Troedyrhiew Farm (75 acres) was £6,000, including the delivering conduit, the preparation of 20 acres for filtration (some of the work being done twice over) and the subsequent laying out of the 55 acres for irrigation. To repay this outlay, the annual charge would be £300 a year. It is quite certain that if the filtration work had not been subject to the disadvantages to which I have referred, the outlay might have been much less;—in fact the whole 75 acres might have been drained, and laid out for *intermittent filtration* for no greater sum than was unfortunately expended in the combined arrangement. The rent (or annual charge) paid by the Board for the 75 acres, I was given to understand would not exceed £375 to £380 a-year. Putting the land and works together, the total annual charge upon the ratepayers of Merthyr if the expenditure had been confined to the 75 acres at Troedyrhiew would have been at this moment £680 a-year, or nearly £9 an acre. The return of money from the crops raised from the whole of the Troedyrhiew Farm may be certainly taken to have reached an average income of £20 per acre, or £1,500 a-year, owing to the local demand for grass and vegetables being quite equal to the supply produced by the farm. The net return, after payment of seeds and labour, which may be taken at £10 an acre, would in such case certainly meet the outgoing of £680 a-year, required to discharge the cost and preparation of the land. By this course of proceedings the ratepayers of Merthyr Tydfil might have been saved the whole of the rates they have now to meet in consequence of possessing

the quantity you put upon it as a maximum; on what grounds do you say that? *A.* I say that under the present arrangement it might be so, because if we put much more on than we are now using, we should damage the vegetation instead of improving it. —*Q.* But suppose you decided upon sacrificing the vegetation, what would your opinion then be? *A. Then I think that we might cleanse the whole of the sewage of the town.*—*Q.* I think you have stated that you had not noticed any sign of the land being overdosed. *A.* No, not so far as the cleansing is concerned.

the distant land, and "*sewage farming*" would not have another instance of failure recorded against it, which, in the interests of agriculture, is so much to be regretted.

It has been attempted to disparage the results arrived at by asserting that there exists in the Valley of the Taff a large quantity of subsoil water which dilutes the infiltrated sewage, and that the analyses do not therefore represent a condition of effluent which would generally be found issuing from the underdrains of intermittent filtration areas. There is no doubt that there is some truth in this statement, but inasmuch as there is very little valley land in Great Britain, by which sewage could be cleansed, which is not subject to subsoil water in a greater or less degree, the fact of its existence rather favours than disparages the adoption of the process, for the more the filtered sewage is diluted, the more nearly it approaches a condition admissible into rivers.

Remarkable proofs of the success achieved.

That the success of the works at Merthyr is not to be set aside by disparagements of this sort has been very appositely proved by certain circumstances very recently communicated to me by Mr. T. J. Dyke, the Medical Officer of the district of Merthyr Tydfil, whose interest in sanitary science is only equalled by his earnest desire to represent the true facts of the case. He states in his letter, dated the 9th September, 1880, that "the filtration areas," which have been so persistently stated to have merged in the surface irrigated farm, in spite of the assertion of Mr. Jones, the Chairman, to the contrary, "are constantly used."

"On more than one occasion during the last three years *the 20 acres prepared by you have had to take the whole of the sewage of* 40,000 *people for two, three, or more weeks together.* The necessity for this has been on each occasion caused by the breakage of the sewage channels which were devised for the conveyance of the sewage to the lands below Navigation Junction. On each of these occasions the areas did their work thoroughly."

Upon my asking the writer, subsequent to the receipt of this letter, whether he did not mean that the sewage of the 40,000 people was filtered through the 75 acres constituting the Troedyrhiew Farm, he replied:

"I mean that the 20 acres virtually took the sewage in emergencies from the sewers above Troedyrhiew. Some portion might be sent over the other 55 acres, but this must have been small, as those portions of the land at Troedyrhiew are let out for grazing and for the growth of

Italian rye grass, so that virtually the bulk of the sewage had to be dealt with by the 20 acres."

But complete as this proof is of the value of Intermittent Filtration as a safety-valve, the most unquestionable evidence of the efficacy of filtration through natural soil is to be gained from the circumstance that the Sanitary Authority of Merthyr Tydfil has admitted or has arranged to admit the sewage of the several neighbouring districts of Aberdare, Mountain Ash and Treharris (Quakers Yard), with a joint population equal to that of Merthyr itself (making the aggregate population amount to nearly 100,000), on to a less area of land than was designed in 1869 to take the sewage of Merthyr Tydfil alone! I state this on the authority of Mr. Harpur, who, in the evidence he gave at the Lower Thames Valley Main Sewerage Inquiry, stated that the combined authorities of Merthyr Tydfil, Aberdare, Mountain Ash, &c., with the population already stated, was being dealt with on 212 acres, including the 75 acres at Troedyrhiew. At the same time he showed that the whole of the 212 acres was not laid out for Intermittent Filtration, but was partly utilised for surface irrigation! By this combination of districts and reduction of area (which would never have been attempted but for the experience gained in Intermittent Filtration at Troedyrhiew) the charge upon the rate-payers of Merthyr, though still great in comparison with what it would have been, had the Troedyrhiew land only been utilised, will be reduced to less than half what it would have been had the original intention of 1869 remained in force, thus affording the most tangible evidence that could be produced of the true value of Intermittent Filtration which in the first instance was regarded with derision and which is still held up by its opponents as an object for public distrust.

Treatment of the subject at the Institute of C.E.

It is not long since Mr. Norman Bazalgette, in a paper he read at the Institution of Civil Engineers, made use of these extraordinary expressions:

"Surely it is time that the Merthyr fallacy is stamped out, and yet the advocates of Intermittent Downward Filtration seem unwilling that it should die. The statements with regard to Merthyr are without foundation or justification."

How strangely will these words read side by side with the experiences just related! Having commenced my apprenticeship to agriculture more than fifty years back, and having joined the Institution of Civil Engineers nearly forty years back,—during which term I have not been idle in engineering works of the kind criticised,—I shall be exonerated from unworthy egotism if I meet expressions aimed so directly at

myself by declaring that I esteem the opportunity I have had at Merthyr Tydfil of giving substantial evidence of the soundness of Dr. Frankland's views on Intermittent Filtration through natural soil as the most fortunate incident of my life. This satisfaction is based on the conviction that it will be only by the adoption of the process in one shape or other, that the reproductive value of human refuse will be realised for the benefit of the country. That the people of Merthyr do not partake in Mr. Bazalgette's opinions is evident by the last words of Mr. Dyke's recent letter. He says:—

"The feeling in Merthyr" (after ten years' observation) "is that the filtration areas at Troedyrhiew were an engineering success. They did the work designed for them perfectly. The process you devised is the right one, and I earnestly hope the authorities of towns will adopt it."

With these facts recorded it is unnecessary to ask whether they do not incontestably prove that the sewage of 1,000 persons may be permanently cleansed on an acre of suitable land properly laid out and properly drained 6 feet deep in spite of the *opinion* of Mr. Harpur, often quoted by detractors though unsupported by any proof whatever, that the capability of soil to cleanse sewage is limited to 500 persons to the acre.

To enable the readers of this treatise to form their own opinion, I append an extract from a letter written by Mr. Harpur to me on the 9th of March, 1872, before he became committed to the opinion referred to, in which he says:—

"You know my objections to your Merthyr scheme were due chiefly to its interference in some measure to my plans, but all that is passed, and having carefully watched the process of Intermittent Filtration in operation here and observed its marked success, I should be fostering a prejudice if I hesitated to give evidence in its favour."

It is simply in the interest of Sanitary Science that I publish this extract, and refer my readers to the evidence of Mr. Harpur which I have previously given as a footnote.

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2. KENDAL, WESTMORELAND.

At Kendal, the Council of the borough running in the opposite course to that followed by the Local Board of Merthyr Tydfil instead of preparing a large farm for surface irrigation, as they had been advised to

Mode of disposal.

do, determined to cleanse their sewage by intermittent filtration through as small an area of land as possible. When the writer was called in by the Council in 1873, he found the population to be about 13,500, the number of houses 2,700 (having about 450 water-closets) the water supply about 400,000 gallons a day, and the quantity of sewage diluted with subsoil water (exclusive of surface waters) varying from 750,000 gallons to 1,800,000 gallons daily, the mean dry weather discharge being 975,000 gallons daily. In wet weather the outflow from the sewers reached 5,000,000 gallons in 24 hours. With these details before him he

Quantity of land recommended.

recommended the use by Intermittent Downward Filtration of 16 acres of "suitably constituted soil" which had already been purchased by the borough, and could be reached by gravitation, and which was capable of underdrainage to the full depth of seven feet. The writer did so in consonance with the view he had already adopted at Merthyr, *i.e.*, that in order to secure permanency of effect it would be well to limit the sewage of 1,000 persons to an acre. The Council, bearing in mind the report of the Rivers Pollution Commissioners that the sewage of 3,300 persons might be cleansed by Intermittent Filtration through an acre of land, however, rejected his advice and determined to limit the area to be

Quantity actually prepared and used for filtration.

utilised to one-third of the 16 acres, and for seven years five and a half acres of land have served, though not very perfectly, the purpose. As if to reduce as much as possible the capability of so small an area to do such an extreme duty, the Council took the earliest opportunity of letting the land to a tenant who naturally considered the production of crops of

Results.

primary importance. The result of limiting the area in the way mentioned and of letting the land to a tenant, who naturally regulates his management by self-interest, is that the intermittent rest which all land should have to prevent nuisance arising from the collection of solid matter upon the surface has been withheld. Nevertheless, Mr. Banks, the local Surveyor of the borough, wrote as recently as September 8th, 1880 (after seven years' trial), that—

"The land at present is as you left it in regard to area, except that the lower part of the field in which the filtration areas were formed has been levelled, and for the last two or three years has been used as rye grass plots, taking of course three or four times the sewage it formerly did. By such use of the 11 acres outside the areas, the latter have been relieved to the extent of one-fifth of the sewage."

Mr. Banks confirms in 1880 the views expressed by me in 1873 when he stated that—

"This outside land can be used as filtration areas with very little

expense, and if I can prevail upon the Corporation to keep it in their own hands we should free the areas for a year, and afterwards work the whole together. *As far as the purification is concerned it is perfect*, and I am convinced that with the 15 acres we have" (16 acres), "we shall always be able to deal successfully with the sewage as far as the purity of effluent and absence of nuisance is concerned. It was a great mistake to let the land; no farmer can make any profit where you have such an enormous volume to deal with on such a small area of land. The tenant has not been applying the sewage intermittently, but running it on to the beds for days at a time, he only works it so as to make his crops pay if he can, never caring if the land becomes less capable of allowing the sewage to pass through it or not. *Looking at the whole scheme I think it has worked even more favourably than you expected.*"

It need hardly be said that although the required purification is so completely secured, and has incontestably proved the soundness of Dr. Frankland's views and the practice I founded upon them, it will not be until the additional 11 acres are properly laid out and used, as Mr. Banks says, in connection with the five and a half acres already prepared, that the treatment of the land at Kendal can be offered as an example to be copied by other authorities.

Owing to the River Kent forming the boundary of the sewaged land on three of its sides, and the land being very porous, the discharge from the underdrains is not constant, and therefore no analysis is given. When the river is low the effluent finds its way through the subsoil into the river itself independently of the underdrains. The advantage derived from the underdrainage is to be found in the fact that the level of the water in the land is maintained at a level no higher than that of the water in the river under all meteorological conditions. Supersaturation, that might occur in times of continued rainfall, is thereby avoided.

Report of Messrs. Rawlinson and Read.

It was with respect to the works at Kendal that the committee appointed by the President to the Local Government Board (December, 1876) went out of its way to represent the cost of Intermittent Filtration on the ratepayers of Kendal to be 4*d.* in the pound; and to compare it with the cost at Banbury and Bedford where Surface Irrigation has been adopted and which they showed to be 1*d.* in the pound! At Rugby they stated the cost to be 1½*d.* in the pound! Such comparisons made in an official report must have had the effect on its readers of disparaging the results at Kendal while exalting those of the three other places referred to. In that Report the cost of the Kendal "*Sewage Farm*" is stated to have been £16,371, and the cost of laying out the filter beds £1,400; the charge of 4*d.* in the pound being

Inaccurate statements.

based on these figures. Now, what are the real facts? The land for which the £16,371 was paid consists of 66 acres in the immediate vicinity of the borough, and was bought by the Council at a price of £248 per acre. Fifty acres out of the 66 acres lying above the main sewer outlet, and costing upwards of £13,000 out of the £16,371, *have never for a single day been used for sewage purposes.* If, instead of charging the cost of the whole of the 66 acres against the disposal of the sewage the proportionate amount paid for the 16 acres which alone received the sewage had been made the basis of calculation the result would have been 1½*d.* in the pound instead of 4*d.*

Turning to the facts relating to Banbury, Bedford, and Rugby, we find that no land whatever has been purchased in either case, but the land utilised has been leased at very moderate rents, viz. :—at Banbury, 130 acres has been obtained for less than £5 an acre = £622 a year; at Bedford, 181 acres at £5 an acre = £917 a year; and at Rugby, 57 acres at £6 10*s.* = £360 a-year. By reference to Messrs. Rawlinson and Read's report it will be seen that Banbury, Bedford, and Rugby are only charged with these rents, while at Kendal it is made to appear that "the Sewage Farm" of 16 acres has cost the borough £17,761, including its preparation!

In the same report it is stated that the cost of preparing the five acres and a-half laid out by me at Kendal for Intermittent Filtration was "£280 an acre." Here again I may fairly ask, what were the facts? The sum of £1,400 was laid out not in preparing the five and a-half acres only,* but in paying for an expensive conduit for the delivery of the sewage to the whole of the 16 acres, and for the partial underdrainage of the outside 11 acres as well. An acreage calculation was therefore altogether inappropriate, inasmuch as the effect on the ratepayers of reducing the area of application is not to be measured by the cost per acre of the works executed on the 5½ acres, but by the *total outlay*, and the rateable contribution of the inhabitants towards its repayment. At Kendal the current outlay in distributing the sewage and in managing the sewaged land is more than met by the produce; the return for which in the shape of rent or profit† goes in reduction of the charge for land and preparation.

* See descriptions of works given in the "Transactions" of the Institution, C.E., Vols. xlviii, p. 205, and xlix, p. 197.

† As an earnest believer in the benefit to be gained by the country at large by an accurate statement of facts relating to land filtration, I protest against the injurious influence of such official misstatements as are here exemplified.

Official misrepresentation of facts.

As a proof of the prejudicial influence of official misstatements it may be pointed out that in a publication entitled "Water Carried Sewage," intended "*for the guidance of Corporations, Boards of Health and Sanitary Authorities*," the authors, Messrs. Robinson and Melliss, basing their statement chiefly on this report, declare circumstantially—

"That the farm *to which the sewage of Kendal flows by gravitation is* 65 *acres in extent;* of a sandy loam upon a gravel bed. Eleven acres of this are used for Irrigation; five for Filtering Beds; and the remaining 49 acres are used for the disposal of the solid matter and sediment from the Tank. The amount paid for the land was £16,371 14*s* 3*d*., or about £252 an acre."

Upon these data Messrs. Robinson and Melliss point out that the charge on the population is 11¾*d*. per head. They add that which the opponents of Land Filtration will do well to study:

"The filtration areas are cultivated and the average annual working expenses during the years 1874 and 1875 have been £223, and the average annual return by sale of produce during the same periods have amounted to £512."

The facts in relation to the land, as already shown, are the very reverse of what is here declared; the only land that is commanded by gravitation consists of 16 acres out of the 66 acres. No sewage touches the remaining 50 acres, and it is no more correct to charge as expenditure on Sewage disposal the cost of the 50 acres not utilised, than it would be to charge one district with the outlay made on another. If, instead of utilising for filtration only 5 acres as here stated, the whole of the 16 acres were laid out for that purpose, no interception of the solid floating matter by tanks would be required. The same 16 acres that would cleanse the liquid might beneficially receive the floating matter. The only substantial objection I have yet heard made to the Kendal works has been that raised to the *emptying of the Tanks* which existed before the filtration areas were made. This emptying takes place probably twice a year, which would not be necessary if the screening operations were confined to the removal of the coarser and heavier constituents only, and the remainder was allowed to flow to the land, and there dug or ploughed in.

3. ABINGDON, BERKSHIRE.

Mode of Disposal.

At Abingdon, where the soil is very open and porous, the sewage is cleansed by Surface Irrigation in combination with Intermittent Filtration in the proportion of four acres of the former to one of the latter. The works have been completed four years.

Population, 6,000.

The population of the Borough is close upon 6,000, and the quantity of sewage discharged daily approximates to 200,000 gallons in dry weather, increased to double that quantity in wet weather, the excess being due to the fact that the private sewers communicating with the public sewers in the town receive the rain run off the back roofs and impervious surfaces connected with the houses. The number of acres constituting the farm is 48 acres, of which 27½ acres were actually laid out for Surface Irrigation, whilst the quantity devoted to Filtration was 6½ acres, but the ground is so extremely porous that the filtration areas are only resorted to when from some special reason the tenant finds that the sewage cannot be advantageously applied to any other part of the farm.* The capability of "getting rid" of the sewage on the filtration areas when it is not wanted on the irrigation land is, however, such an advantage that the Council of the Borough have been enabled to let the land, with the sewage, at £4 10*s.* an acre, its agricultural value as ordinary farming land being about half that amount. Instead of finding the sewage too much for the land, the tenant has applied to the Council to allow him to discontinue the application of sewage to about eight acres out of the 27½ acres devoted to Surface Irrigation which he proposes to lay down to permanent pasture. The land laid out for filtration is divided into five beds containing nearly an acre and a quarter each, and such is the absorptive powers of the soil that the 200,000 gallons forming the daily outflow has been applied to one area only for several weeks together, without overfilling

Extent of Land purchased, 48 acres (34 acres only sewaged).

Daily Outflow of Sewage, diluted with subsoil water, absorbed by 1¼ acre.

* It is to be regretted that the tenant does not maintain more perfectly than he does the furrows of the filtration areas, and use them in the way intended, for he suffers from the injury done to his growing crops by "flooding" his other lands and by the accumulation of solid matters on their surface.

the furrows. A deputation from Salisbury, indeed, paid a visit to the farm in May last (1880) and reported that—

"Half an acre will take the day's sewage, and seven acres of rye grass will take the sewage during the summer."

(—a fact which may be readily abused if intermittency is neglected).

Experience at Abingdon indeed has incontrovertibly shown that, with the most favourable soils, the liquid refuse of 3,300 people may be dealt with successfully on a single acre as suggested by Dr. Frankland, the only condition essential to success being that intermittency of application shall be adopted.

Effluent.

The effluent from the sewaged land of Abingdon, which is mixed with a good deal of subsoil water, having been analysed by Doctors Tidy and Woodforde, and by Professor Attfield, has been declared "equal in purity to some waters used for drinking." The quantity of albuminoid matter (yielding 10 per cent. of nitrogen) was found by the last-named chemist to be ·07 of a grain in a gallon and the ammoniacal matter (yielding 10 per cent. of nitrogen) ·02 of a grain in the same quantity. *See Standards previously given.*

Absence of smell on land.

The absence of smell from the surface of the land is so perfect that, although a public footpath runs directly through the farm, the Town Clerk, Mr. Bromley Challoner, wrote me very recently (after three years' experience) that "*no complaint whatever of nuisance has ever been heard.*"

Cost of preparation per acre.

The cost of preparing the land for Irrigation has been a trifle over £70 an acre, whilst that of preparing the filtration areas has been £85 an acre. These figures include the delivering conduits, carriers, chambers, roads, iron fencing, quick fencing, and other incidental expenses, as well as engineering charges, and should be compared with the "reported" outlay at Merthyr and Kendal. The total outlay in preparing the 34 acres of land to receive the sewage, and in the building of a farmstead and cottage for Bailiff, has amounted to £3,470, making with the cost of the land (48 acres in the whole) a total outlay of £10,640. The farm (48 acres) being let on lease for £225 a year, yields an income equal to 2⅛ per cent. on the cost of land and preparation, which goes in reduction of the district rate; and all expense in distribution is saved to the Borough.

Income from Land and Sewage, equal to 2⅛ per cent. on total outlay.

It will be observed that, as the preparation of the land, *including the erection of cottage and farm buildings*, costs £3,470, the total acreage outlay only just exceeded £102 an acre, which is not half the

amount stated to have been laid out at Merthyr Tydfil and Kendal, without any buildings whatever!

Sludge.

At Abingdon there is no separation of the "sludge" from the liquid before it is applied to the land for purification. Whatever passes the screens, and is raised by the pumps, is distributed over the surface by contour grips when the sewage is used for irrigation, or by the furrows when it is used for filtration, and no difficulty whatever is experienced in either case, nor is any smell perceptible at a distance of 20 yards. So far from any difficulty or objection having been experienced from the retention of the "sludge" in the sewage, the tenant has complained that he has not sludge enough, and that the liquid is absorbed by the land too quickly. Two hours after the cessation of pumping, no sewage liquid is to be seen on the farm.

It has been observed in this case—as it has also been in the cases of Merthyr and Kendal—that the soil utilised is *exceptionally* free and percolative. This, however, is not the case, for in nine cases out of ten the same rapidity of absorption, and the same results as to quality of effluent, have attended the operations. It would be difficult to find in England a parallel instance where the rent obtained for land and sewage has been equivalent to 2⅛ per cent. on the total cost of land and its preparation.

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4. FORFAR, SCOTLAND.

Population 12,500.

This Burgh is the principal town of the County of Forfar in Scotland. It has a population of about 12,500.

Mode of disposal.

The mode of disposing of its sewage is that of Intermittent Filtration combined with Surface Irrigation in the proportion of one acre to three. It was the first operation of its kind in Scotland. Previous to the adoption of this treatment the sewage flowed into the Loch of Forfar, the property of the Earl of Strathmore, who, to protect his Estate from injury by the pollution of the Loch, took proceedings through the Court of Session and compelled the Sanitary Authority (the Commissioners of the Police) to adopt a means of cleansing its sewage.

Quantity of Sewage.

The quantity of sewage discharged in dry weather, varied from 400,000 to 600,000 gallons daily.

In 1877, Mr. Willet, C.E., of Aberdeen, was employed to effect the sewerage of the town, whilst Messrs. Bailey-Denton and Co., of Whitehall Place, London, were called in to advise as to the disposal of the sewage,—which resulted in the adoption of the treatment men-

tioned. The Commissioners purchased for the purpose, at a cost, with expenses, of £4,000, "Orchard Bank Farm," containing about 40 acres of land adjacent to other property belonging to the Burgh, which may ultimately, if required, be utilised for sewage purification.

Extent of land purchased, 40 acres.

The disposal works were executed in 1878 and 1879, at a cost of £1,450, or £60 an acre, and when accepted from the hands of the engineers, were described in the local paper in the following terms :—

"The quantity of land prepared at Forfar to receive and cleanse the present sewage is confined to about 24 acres only out of the 40 acres, and the mode of treatment adopted is Intermittent Downward Filtration, combined with Surface Irrigation. The area of land devoted to Intermittent Filtration is seven acres, leaving 17 acres for Surface Irrigation. The soil is of a free and open character, sandy and gravelly in parts, though occasionally partaking of a somewhat loamy character. The land may be described as admirably suited for the filtration of sewage, but in order to avoid all chance of supersaturation, a main underdrain, with subordinate drains, has been laid, which will keep down the subsoil water, and secure aëration, and so allow of perfect percolation of the liquid distributed over the surface of the ground.

Acreage Sewaged, 24 out of the 40 acres.

"The filtration areas are laid out in a series of terraces, each terrace being on a perfect level, to be intersected by main furrows traversing their whole length, with branch furrows cut at right angles to the main ones. The main furrows are deeper than the branch furrows, in order that they may receive the solid matter floating in the sewage, which will deposit itself in them, and allow the liquid to be distributed by the branch furrows evenly through the soil. The intermediate ground between furrow and furrow is planted with vegetables, the roots of which help themselves to what they require of the sewage, and will yield abundant crops.

"The terraces forming the filtration areas, and the delivery of the sewage to them, are so arranged that each terrace can receive its quantum of sewage separately from the rest, or two or three can be served at the same time according to the quantity of sewage to be disposed of. After they have received 'their fill,' the sewage will be turned on to other terraces, which in their turn will receive their quantum. By this means that intermittency of application and consequent aëration, upon which the oxidation of the putrescible ingredients of sewage depends, will be effected.

"The fields laid out for wide irrigation are prepared very differently from the filtration areas, inasmuch as the sewage is distributed over them on the 'catch water' system, without any great alteration of surface configuration. The distributing carriers follow the natural contour of the land. When filled the sewage overflows their edge and runs down the natural slope of the land towards the next carrier, which is again filled to overflowing. The whole will be under the charge of the 'waterman,' who controls and distributes the sewage in suitable quantities by means of 'stops,' which he places in the carriers when required to check the flow."

Crops and return.

The land was partially sown and planted in the year 1879. After more than 12 months' experience the convener of the Water and Sewage Committee, Mr. Whyte (now Provost), *i.e.*, on the 18th day of October, 1880, reported to the Police Commissioners that from the experience they had gained it was evident that the Sewage Farm would not only pay itself, but perhaps the charge for the pumping station besides. In support of this he laid before them the following tabulated statement of the year's produce :—

SEWAGED LAND.

East Field—Rye Grass.

	£	s.	d.	£	s.	d.
Crop No. 1—21 tons 14¾ cwts.	20	5	4			
„ „ 2—26 „ 5¼ „	19	13	4½			
„ „ 3—34 „ 7¼ „	26	12	8			
„ „ 4—34 „ 3 „	25	12	3			
„ „ 5— 9 „ 5½ „	6	19	1½			
5 acres 6 poles, 125 tons 15¾ cwts., ... or £19 13*s.* 4*d.* per acre.				£99	2	9

West Field—Rye Grass.

Crop No. 1—21 tons 12¾ cwts.	19	7	0½			
„ „ 2—28 „ 14½ „	24	14	5			
„ „ 3—34 „ 19 „	29	0	9			
„ „ 4—25 „ 9½ „	19	2	1½			
5½ acres, 110 tons 15¾ cwts., ... or £16 13*s.* 6*d.* per acre.				92	4	4

Filtration Areas.

Per Acre.	tons.	cwt.	lbs.					
Crop No. 1—Cabbages ...	10	3	4	...	13	3	11	
„ „ 2—Carrots ...	55	6	8	...	29	2	9	
„ „ 3—Turnips ...	12	13	0	...	6	12	10	
„ „ 4—Mangolds ..	21	0	0	...	43	17	10	
„ „ 5—Swedes ...	13	6	9	...	18	5	9	
							111	3 1

Outer Lands Sewaged, &c.

2¾ acres of turnips, £8 per acre	22	2	11		
Potatoes, 5 tons Myall's Kidneys, £4 per ton	20	0	0		
Carried forward	42	2	11	302	10 2

	£	s.	d.	£	s.	d.
Brought forward	42	2	11	302	10	2
Potatoes, 5 tons Regents and Champions, £3	15	0	0			
Savoys—say 1½, £20	30	0	0			
Barley, 2 qrs, 25s.	2	10	0			
				89	12	11
Rent—Mr. Mount, Farm House, &c. ...	30	0	0			
Rent—Mr. Graham, Land not sewaged ...	20	2	7			
				50	2	7
Total receipts from Farm				£442	5	8

Mr. Whyte, continuing, said "they might reasonably look forward to even better results from the filtration areas. Coming to the debit side he took the cost of Orchard Bank and the expenses, £4,000, at 4 per cent.—and £160 was the rent of the farm. The expenditure for laying out the farm amounted to £1,450, to which some little additional expense had had to be added, and he put the total at £1,500, or at 4 per cent., £60. All the expense of working did not apply to the crop, but he had put down £150, which he believed would cover the expense. There was then a total of £370 as the cost of the farm. There was thus a balance of £72 5s. 8d. in favour of the farm on the season."

At the same meeting the Commissioners came to the following resolution, which was signed by the Provost of the Burgh and forwarded to the Engineers:—

Forfar Sewage Disposal.

"After the experience we have now had of the sewaged land at Orchard Bank, we have pleasure in expressing our entire satisfaction with the manner in which you have designed and carried out the works for the disposal and cleansing of the sewage of this Burgh. With respect to the actual cost of the works we find that you have prepared seven acres for Intermittent Filtration, and 17 acres of hilly land for Surface Irrigation, and have distributed the sewage over the whole by glazed stoneware and iron pipes connected with chambers of masonry for the sum of £1,450. This amount includes the wages of Mr. Jonas Harris, the Clerk of Works, for more than a year, during which time he has attended not only to the cultivation of the farm, in addition to the work of preparation, but to sundry matters connected with the sewerage of the Burgh. It also includes the construction of roads, the alteration of fences, the purchase of weighing machine, and the payment for seeds for land, as well as other acts of husbandry. The filtration areas are capable of absorbing and cleansing the whole of the sewage of the Burgh when it is not distributed over the land laid out for Surface Irrigation. Vegetable crops of considerable weight are grown on the

Preparation cost £60 per acre, including Roads, Fencing, &c.

former, while rye grass occupies the latter, and a fair return is to be anticipated. The effluent is always most satisfactory.

Effluent.

"Passed at a meeting of the Local Authority of the Burgh of Forfar, held on the 18th day of October, 1880, and signed for and on behalf of the said Local Authority by me,

"JOHN LAWSON JUNR.,
"PROVOST."

These particulars so thoroughly confirm the views already expressed that it is unnecessary to add any further explanation, but they may serve to show that with a combination of the two treatments—Intermittent Filtration and Surface Irrigation—not only may ratepayers be relieved of *loss* in the disposal of sewage, but that a profit may be gained after payment of interest on outlay.

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5. GREAT MALVERN, WORCESTERSHIRE.

Here Surface Irrigation had been in practice for some years before the present treatment was adopted. Up to the year 1874 the sewage was discharged from that portion of the district known as Great Malvern on to land in the Pool Brook Valley, which was partly devoted to permanent pasture, and partly to the growth of Italian Rye Grass, without that careful preparation of the surface which is necessary if sewage is to be absorbed by the soil and those abuses avoided which are due to the overflow of sewage from the surface of the land into the outfall streams. At Malvern the overflow was greatly increased by the heavy and sudden downfalls of rain which characterise the locality.

The land upon which the sewage was treated in the way mentioned was held by a tenant who found it impossible to avoid the collection of fæcal matter in slacks and hollows of the surface and the washing off of such solid substances into the brook on occasions of heavy rainfall. The consequence was that Sir Edmund Lechmere, Bart., M.P., living at the Rhydd, on the banks of the Severn, at the junction of the Pool Brook with that river, found that the off-flow from the sewaged land polluted his water supply and brought down to his residence unmistakable signs of sewage. On his representation of the facts the Local Board decided to alter their mode of sewage disposal.

Position and Rainfall.

The town of Great Malvern stands upon the somewhat precipitous

slopes of the hills known as the Malvern Hills, and the locality being subject, as stated, to heavy falls of rain, a large quantity of water is thrown off the surface, the greater part of which had been admitted into the sewers to find its way by them to the sewaged land at the time when Sir Edmund Lechmere's complaint was made. More than two inches of rain have not unfrequently fallen in 24 hours, and as much as 8,000,000 gallons have been thrown off the area covered by Great Malvern.

Surface Water thrown off.

The Local Board having sought advice from the writer's firm it was determined to separate, as far as practicable, the surface waters from the sewage proper, and to exclude the former from the sewers. It was further determined that in lieu of Surface Irrigation alone as previously practised, the process of Intermittent Filtration in combination with, and as a safety-valve to, Surface Irrigation should be adopted, and that more pains than had hitherto been taken should be taken to prepare the surface over which the sewage was distributed in order that it might be absorbed rather than thrown off. The work of separation, however, could not well be extended to the whole of the surface tributary to Pool Brook. The proportion to which a means of interception could be favourably applied was limited to about two-thirds of the whole tributary area, or about 230 acres,—leaving rather more than one-third still discharging its surface waters into the sewers.

Quantity of Rainfall intercepted and excluded from Sewers.

By this separation at least 5,500,000 gallons of surface water have been removed from the sewers in times of storms, and the land now used for the cleansing of the sewage has been relieved to that extent without depriving the outfall stream of the district of its natural supply for any length of its course.

Population.

The resident population contributing sewage to the sewers of this portion of Malvern was estimated in 1874 at 4,000, increased in certain months constituting "the season," to about 6,000, but as the popularity of the district as a place of health-resort is very great it was necessary to make a large provision for the future disposal of the sewage.

Present dry weather outflow.

The present quantity of sewage proper measured by the water supply amounts to 150,000 gallons a day, but in looking to the dilution due to subsoil water which raises it to 350,000 gallons, and to the future increase of population, it was considered desirable to provide for four times the water supply, as the dry weather discharge, whilst it

was assumed that in wet weather the discharge might exceed 2,000,000 gallons in 24 hours, after the separation referred to.

Quantity of land utilised in cleansing 40 acres. How divided.

To provide for such discharges the Local Board purchased 40 acres of land about a mile lower down the Pool Brook Valley than the land which had hitherto been utilised, at a cost of £7,000. Of this quantity 11½ acres have been laid out for Intermittent Filtration, 24 acres for Surface Irrigation, and 2½ acres for the growth of Osiers, through which to pass the surplus water (beyond that which the land is intended to cleanse) in times of rainfall; leaving the remainder (2 acres) to cover the space taken up in roads, barrow paths, tanks, &c. The land is of a mixed character on the New Red Sandstone formation, consisting of marl and clay intermixed with a free rubbly earth or gravel, of a sufficiently hard texture to supply the material for the roads on the farm. The filtration areas are 11 in number, and together form a square block in the centre of the 40 acres where the freest description of its soil exists, each area approximating one acre in extent; and such is the absorbent character of the soil now that it is thoroughly drained that the whole of the present dry weather sewage (350,000 gallons) has been disposed of for several days in succession on a single area only, and an effluent of a superior character obtained at the same time. With this fact established and the power of applying the sewage intermittently to any of the 11 areas it soon became manifest that the quantity of land devoted to filtration would be of itself sufficient to cleanse the sewage to be dealt with for many years to come. Having, however, the command of 24 acres of Surface Irrigation, which will take the sewage whenever it will be profitable so to apply it, the Board will be made doubly secure; and if it should be desired hereafter to concentrate sewage from other districts on the same land (as has been done at Merthyr Tydfil) this object can be accomplished with certainty also.

Character of soil.

Intermittent Filtration areas.

Further land can be sewaged by gravitation, if hereafter found desirable.

Beyond this combined arrangement there exists the capability of applying the sewage to other land, outside the 40 acres, which exists at a level to receive it by gravitation. The main delivering conduit, in fact, has been laid at a height to command additional land if the Board should determine either to increase the size of their sewage-farm, or to sell the sewage for use on neighbouring farms. Moreover, the great advantage of having filtering ground sufficient of itself to cleanse the whole of the sewage will be experienced in the present case in the capability of withholding sewage from the irrigation land whenever it

is desired to grow cereal crops, hops, or any other plant or vegetable which would better answer the purpose.

Cost of preparation of land.

The cost of preparing the whole of the 40 acres for the reception of the sewage has not exceeded £3,300. This includes the underdrainage and the surface formation of the whole, as well as the construction of tanks, delivering conduits, and distributing chambers, the formation of roads, and osier beds, iron fencing, entrance gates, osier planting, the flushing arrangement of the underdrains, the charges of the Engineers, and wages of Clerk of Works. The total cost of land and preparation has not exceeded £10,100.

Roads.

The difficulty of carting over land of which clay and marl are constituents in winter and spring, when heavy loads of savoys and other cabbages have to be removed to market, has rendered it necessary to form roads of a somewhat expensive character.

Effluent.

A sample of the effluent from the underdrains was taken and submitted for analysis—after the sewage had been on one area for several days, considering that such would be a very severe test of the character of the effluent. The following is the analysis of Professor Attfield:—

"*Analysis of 'Effluent from Great Malvern.'*

"17, Bloomsbury Square, London, W.C.,

"*December 16th*, 1880.

"The appended data show that the amounts of impurities in this effluent are well within official limits, and hence that it is admissible into any ordinary river.

"The first of the following two columns of figures shows parts per 100,000, the second column parts per 70,000 parts (grains per gallon) of the respective substances contained in the effluent.

	Parts per 100,000 parts.	Parts per 70,000 parts or grains per gal.
Total solid matter, dried at 212° F. ...	37·2	26·
Nitrogen (as ammoniacal matter)	·33	·23
Nitrogen (as organic matter)	·024	·017
Nitrogen (as nitrates, and much nitrites) ...	·24	·16
Chlorine (as chlorides)	3·3	2·3
Temporary hardness (as chalk grains or degrees)	11·	8·
Permanent hardness (as chalk grains or degrees)	13·	9·
Total hardness (as chalk grains or degrees)	24·	17·
Lead or copper	none	none

"The effluent is fairly clear and almost bright.

"(Signed) JOHN ATTFIELD."

Storm water osier bed.

It will be seen by the accompanying map that Osier Beds for the cleansing of such storm water as may be suddenly thrown down on the farm in excess of the quantity the land will absorb, are situated at the lowest margin of the land, next the outfall stream. They were formed out of ground of uneven surface. The object of these Osier Beds is not that of filtration *through the soil*, but simply to arrest the solid matter floating in the storm water on its way to the outfall stream, to effect which the osiers are planted on ridges in areas formed on several levels, descending by steps to the outlet. By this means the storm water passes from one level to another and deposits such solid matter as it may contain in the furrows.

This example of Malvern is given to show that in a district where it cannot be said that the conditions are in any way exceptional, the combined treatment may be adopted with a certainty of success, and at no unreasonable charge on the ratepayers. The farm is, at present, in the hands of the Board, who intend to erect farm buildings upon it for the housing of milch cows, pigs, &c.

Should the income after payment of current expenses of labour, seeds, &c., reach £5 an acre only, the return on the cost will be £2 per cent. There is every reason to believe that as the distribution is so arranged as to involve the least outlay in labour, the net income will be much greater.

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6. HALSTEAD, ESSEX.

Population 6,000.

The Urban District of Halstead has a population closely approaching 6,000, and therefore resembles in that respect the condition of Abingdon.

Mode of Disposal.

The mode of disposing of its sewage is that of Intermittent Filtration combined with Surface Irrigation, and the use of Osier Beds as a means of cleansing storm waters in times of heavy rainfall when sudden excesses would overcharge the land.

Outflow from Sewers.

The daily dry-weather outflow from the town barely exceeds 70,000 gallons, but—although the sewerage was designed on what was termed the separate system to exclude surface waters—the discharge from the sewers in wet weather occasionally far exceeds 1,000,000 gallons in the 24 hours.

Extent of

The land to which the sewage is applied is of a mixed character, the

soil consisting of clay, gravel, and sand. The extent is 15½ acres, of which rather more than 6 acres are devoted to Intermittent Filtration, the same quantity to Surface Irrigation, and 1¼ acres to the growth of Osiers. The remainder covers roads, banks, paths, and a spoil-bank to be used for seed beds.

land utilised, 15½ acres.

The sewage discharged from the town flows by gravitation to the filtration areas, which are five in number, and vary in extent from an acre and a half to less than one acre. They are laid out perfectly level, at heights differing from one another according to the form of the natural surface; the highest area, as finished, being 4½ feet above the lowest.

Intermittent Filtration.

Land reached by simple Gravitation, 6 acres.

The land laid out for Surface Irrigation occupies sloping ground rising gradually from the filtration areas, and a wind engine working a Noria has been erected to lift the sewage to the top of the slope, which is 20 feet above the invert of the sewer mouth. This engine necessarily only comes into action when the force of the wind is sufficient to work it. Pains have been taken to make the most of the wind, and whenever it raises the sewage, or part of it, the filtration areas are correspondingly relieved. With a fair wind the whole of the sewage should be raised, and then the filtration areas will be freed from the sewage altogether. It is calculated that for at least 100 days in the year, the wind will relieve the areas of sewage, and if so it will be a cheap motor. Its use will accord with that intermittency of application which is so essential to the purification of sewage, inasmuch as although it will only be when the wind is sufficient to lift the sewage that the filtration areas will be relieved, yet the aggregate number of days when that power will be called into play being at least equal to one day in four, a very material respite will be gained:—and such advantage will occur precisely in that way which will most economically conform to the process of *Intermittent* Filtration.

Surface Irrigation. 6 acres.

Wind used as a motor for lifting the sewage for Surface Irrigation.

The use of wind for the raising of sewage to land* is a feature,

* In spite of the fickle character of this power it may also be found of value as a motor in the supply of water to small communities wherever there exists a sufficient quantity which can be lifted from a water-bearing stratum beneath, and stored in reservoirs on the surface. It is seldom that a week passes at any time of the year without a recurrence of sufficient wind to raise some, though it may be but a little, quantity of water, and it is not too much to say that with an ample amount of storage, many a village now dependent on polluted ponds and shallow wells might be supplied with the best potable water at a comparatively small cost.

therefore, to which attention may be well given in all cases where a part of the land to be utilised may be reached by gravitation, whilst the remainder must be served, if reached at all, by pumping.

Osier beds for clarifying storm waters.

The Osier beds, intended to clarify storm waters, when they dilute the sewage beyond the quantity which the land is intended to cleanse, occupy a narrow strip of land running alongside the river from the lowest filtration areas to the main outlet. These Beds are severally laid out (*see* Map), as at Great Malvern, in levels, and so arranged that the storm water, having passed through them consecutively and deposited such solid matter as will be arrested in the furrows, will reach the outlet into the river in a clarified state—the intention being to check, as far as possible, by the successive levels, the onward rush of the water and so encourage deposition in the furrows whenever the beds come into use.

The delivery of the sewage to the filtration areas is so designed that when the full quantity they are intended to purify is exceeded by sudden storms the excess will pass onward to the river *through the Osier Beds* instead of into the Colne direct.

From the experience already gained in the use of the combined system here adopted, it would appear that *the six acres of land devoted to Intermittent Filtration* might be found of themselves, if properly managed with strict regard to intermittency of application and the maintenance of the furrows at the different depths prescribed, sufficient to cleanse the whole of the dry-weather outflow. Relieved, as the filtration areas will be at times when the wind engine comes into action—equal in the aggregate to one quarter of the year—all doubt of their constant and future efficiency is removed.

Cost of the preparation of the land.

The purchase and the preparation of the land, including the underdrainage, the construction of screening tanks, delivering conduits, and distributing chambers, embanking the land against river floods, fencing, osier planting, road making, engineering, payment of the wages of the Clerk of the Works, and other incidentals, has cost on the whole £3,500. When giving this cost it should be stated that the earth work in levelling the areas and osier ground has been very considerable.

Cost of wind engine and tower.

The outlay on the wind engine and tower, with well, pumps, &c., has been £275, but this should not be charged to the disposal works, but to the sewerage of the town.

Effluent

A sample of the effluent taken from the underdrains before the

ground was perfectly consolidated, and when it was considered to be in its worst condition, and affording the severest test, was analysed by Professor Attfield, F.R.S., and the following figures show in parts in 100,000 parts, the respective substances contained in the effluent:—

Total solid matter dried at 212° F. ...	63·
Nitrogen (as ammonia)	·190
Nitrogen (as organic matter)	·033
Nitrogen (as nitrites and nitrates) ...	·49
Chlorine (as chlorides)	9·4

At present, the land is in the hands of the Board. Should the net income equal £5 an acre, the return to the ratepayers will be £2 per cent. in the cost of land and its preparation.

Having supported the cases of Merthyr and Kendal by four cases selected from my own practice taken from the north (Forfar), the south (Abingdon), the east (Halstead), and the west (Malvern), where the land operated upon has been of that character which would come within the definition of "suitably constituted soil," I will now describe two cases which, though successful, the soil utilised cannot be considered equally suitable.

The four instances, from 3 to 6 inclusive, if fairly considered, will not only have proved the soundness of Dr. Frankland's views and have justified the works carried out at Merthyr Tydfil and Kendal, but will satisfy engineers that these latter works, which have been so often described as "exceptional," are in no way deserving that character, inasmuch as the four cases by which they have been here supported are illustrations of what has been done in four of the widest surface formations known to exist in the geology of Great Britain, viz.: the superficial soils or drifted matter covering (1) the primary formations, (2) the oolitic beds, (3) the London clay, and (4) the marl of the New Red Sandstone.

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7. BARNSLEY, YORKSHIRE.

Character of soil utilised.

The instance now about to be described—Barnsley—is one which will be interesting to many, because the land there utilised for Intermittent Filtration would be commonly called "clay," consisting as it

does of a loam, with a certain proportion of alumina in it, from the whole of which bricks, pipes, and pottery have been made.

Population 25,000.

The population of Barnsley in 1811 (70 years back) was 5,000. It had increased from that time up to the time when the present mode of sewage disposal was decided upon to 25,000. As Barnsley is a manufacturing town it may be useful to state that the number of houses at the present moment probably amounts to 5,000, and that there exist in the Borough 25 factories, 8 collieries, besides Dye Works and Bleach Works, several foundries, and a tannery. A considerable quantity of trade refuse is discharged into the sewers.

Number of houses and trades.

Quantity of sewage discharged.

The quantity of sewage in dry weather issuing from the sewers was found, when gauged in 1874, preparatory to the works afterwards carried out, to vary from 600,000 to 700,000 gallons per diem, whilst on occasions of storms the quantity of water thrown off the impervious surfaces of the town into the watercourses traversing it amounted to several millions of gallons.

In devising the sewage disposal works it was considered that if provision was made for the cleansing by Intermittent Filtration of 1,000,000 gallons as the dry weather outflow, increasing to 1,500,000 gallons in 30 years, it would be ample, assuming that steps were taken to exclude, as far as practicable, Surface Waters from the sewers, and that means were taken by overflows to discharge from the sewers into the River Dearne those excesses which the land could not absorb in times of heavy rainfall.

This design has been carried out, and the quantity of sewage which has actually been delivered to the selected land in dry weather has been found to amount to rather less than 700,000 gallons, whilst the quantity which has passed the Storm Overflows in wet weather and reached the land, has been found to approach 2,000,000 gallons in 24 hours

Land purchased to cleanse the sewage. How prepared.

The land purchased by the Corporation amounted to 78 acres, for which a *very high price* was paid, but as it was the only land that could be reached by gravitation, some compensation for the high price was gained by this advantage. Of the 78 acres, 30 were divided into 3 areas of 10 acres each, and laid out for Intermittent Filtration,—about 20 acres for Surface Irrigation, and rather more than 2½ acres for the growth of Osiers for cleansing those sudden excesses brought down to the farm, but which the land would not absorb in times of rainfall. The remainder of the property is made up of a water-mill and adjacent land. A con-

siderable portion of the last may be utilised for sewage cleansing hereafter, if and when necessary, and the motive power of the mill may be applied to the lifting of a portion of the sewage to higher ground should it be found desirable so to relieve the farm.

Sludge.

The sewage, as it is discharged from the town, passes through screening tanks which arrest coarser and heavy matters only, and allow the smaller particles to float on with the sewage to the land, where, after its collection in the furrows prepared to receive it, it may be thrown out on the surface of the ridged land and ploughed into the soil. When once dry it assists in improving its percolative powers.

How dispose of.

Analysis of soil.

The soil was analysed by Dr. Voelcker at three different depths and was found to contain the following ingredients:—

"ANALYSIS OF THE SOIL USED AT BARNSLEY FOR INTERMITTENT FILTRATION

Analytical Laboratory,
11, Salisbury Square, Fleet Street,
November 26th, 1878. London, E.C.

Soils dried at 212° F. Marked—

	At 2 feet.	4 feet.	6 feet.
Organic matter and water of combination	6·85	6·41	5·27
Oxide of Iron and Alumina	13·31	13·36	13·10
Carbonate of Lime	1·29	·74	·44
Magnesia and Alkalies, &c.	1·01	1·40	·95
Insoluble Silicates and Sand	77·54	78·09	80·24
	100·00	100·00	100·00

(Signed) AUGUSTUS VOELCKER."

As to the clogging of the soil.

After the sewage had been on the land, and the soil had been fully performing its filtering functions, a sample of it taken a foot below the surface was sent to the same eminent chemist, and he reported that—

He "could not recognise any indication of clogging by sewage matter," and added, "there is no excess of sewage matter, or, I should rather say, there is no sewage matter, as such, in the two samples of earth you sent me,—there is not a trace of offensive matter in either sample."

Experiments testing the

In order to test the absorptive capability of the soil, a series of

absorptive powers of the land.

experiments were made before the analysis last referred to was made :— the quantity of sewage delivered to the land was gauged daily for ten weeks and five days and a record kept of the extent of land to which the sewage was applied daily. The result is shown on the accompanying diagram, which distinguishes (1) the three different areas which received the sewage during the whole period; (2) the quantity of sewage discharged from the town each day; (3) the number of acres receiving it; and (4) the proportion absorbed per acre. Crops were growing on the surface. At no time did the sewage overflow it.

Effluent analysed.

The effluent water from the underdrains during the period of time embraced by these experiments was analysed by both Professor Attfield, F.R.S., and Dr. Meynott Tidy; the former found the proportion of albumenoid organic matter yielding 10 per cent. of nitrogen to be ·14 of a grain in a gallon, and the latter ·12 of one part in 100,000 parts.

By increasing the number of underdrains, so as more perfectly to aërate the subsoil, the percolative powers of any land may be increased; and these experiments have served to prove that with additional drains in the filtration areas at Barnsley, a larger quantity of sewage may be passed through them than at present; great care being necessary when applying sewage to effect even distribution and to avoid, as far as possible, running it directly over the drains.

At Barnsley, where the soil, though clayey, is not dense, having been found by analysis to contain in its natural condition about 80 per cent. of insoluble silicates the sewaged land was rendered more porous by mixing with the surface soil a large quantity of ashes made by burning a proportion of it when the filtration areas were laid out and levelled. It is therefore not so liable to crack when properly used as many loamy soils.

Outlay.

The cost of preparing the 52½ acres of land laid out for Filtration, Surface Irrigation, and Osier Beds, has been £5,313 14*s.*, including drainage, service conduits, and distributing chambers, roads, embankments, outfall cut, bridges, and incidental works. This sum covers money spent in clearing the River Dearne, as well as the construction of the screening tanks and the rebuilding of the Mill Weir. The outlay in incidental works, independent of the actual preparation of the land, has, in fact, been almost as much as the land preparation itself.

The land is at present in the hands of the Board.

Since this treatise has been in the press, the following satisfactory analysis of the effluent has been made by Professor Attfield :—

"The first of the following two columns of figures shows parts per 100,000 parts, the second column parts per 70,000 (grains per gallon) of the respective substances contained in the effluent:— Effluent.

	Parts in 100,000 parts.	Parts in 70,000 parts (or grains per gallon).
Total solid matter, dried at 212° F. ...	44·	31·
Nitrogen (as ammoniacal matter)	·017	·012
Nitrogen (as organic matter)	·012	·008
Nitrogen (as nitrates—no nitrites)	·83	·58
Chlorine (as Chlorides)	4·	2·8
Temporary hardness (as chalk—grains or 'degrees')	6·	4·
Permanent hardness (as chalk—grains or 'degrees')	17·	12·
Total hardness (as chalk—grains or 'degrees')	23·	16·
Lead or copper	none	none

"The effluent is inodorous and fairly clear—almost bright.

"(Signed) JOHN ATTFIELD."

8. HITCHIN, HERTFORDSHIRE.

This case, which was attended with several drawbacks, resulting from the character of the sewerage of the district as well as from the nature of the land utilised, presents some important considerations, for it shows that in spite of the difficulties experienced, an effluent admissible into running streams may be secured with certainty from filtration through peat of a boggy nature. Local circumstances affecting Hitchin.

Hitchin is situated geologically at the base of the northern escarpment of the London basin,—at the junction of the chalk with the Greensand formation. The River "Hiz" takes its rise in this escarpment, and runs through the town. The land on each side of this river consists for the most part of peat mixed, where shallow, with gravel, sand and clunch, and the land selected for the cleansing of the sewage was situated on its banks. The sewage flows by gravitation to this land, which is about half-a-mile below the lower end of the town.

Hitchin was one of the earliest places sewered after the passing of the Public Health Act, 1848, at a time when the ruling principles upon

which sewerage works should be conducted were not as well understood as now. The sewers of the whole town, consisting of glazed socket pipes of various sizes, were jointed with clay, whilst the main sewer, with no other sort of jointing, was laid for nearly the whole distance through the town under the river itself. The surface waters from roads, roofs, and paved surfaces were purposely admitted into the sewers, for flushing, and as the ground upon which the town stands was exceedingly wet, owing to the geological features to which reference has been made, it only required the pressure due to the sudden influx of surface waters into the sewers to disturb the jointing, and admit copiously the subsoil water. The streets and roads contributing surface waters have rapid inclinations, and the sewers laid in them necessarily partake of the same condition. The effect of this state of things upon the outfall sewer was to cause rupture at its joints and to admit water from the river into it.

Report as to mode of sewage disposal, 1874.

In 1874, when the Local Board sought advice on the disposal of the sewage, it was explained that this defective condition of the main outfall sewer would be rectified by the substitution of a new sewer following a course independent of the river. At the same time it was understood that the rain falling on impervious surfaces within the town, as well as other foreign waters (such as those from the public baths and private springs), would be excluded from the sewers, leaving tributary only such subsoil water as found its way into the branch sewers of the town, and which could not practically be withdrawn.

Population 8,000.

The present population of the town is between 7,000 and 8,000; and a somewhat rapid increase may be expected.

Water supply.

Exclusive of the water consumed in one important trade, that of a fellmonger, who takes what he uses direct from the river, the general supply of the town by public service and from private sources amounted in 1874 to between 100,000 and 120,000 gallons a-day, and this constituted then, as it does now, the "sewage proper" of the district.

Land required for the cleansing of the sewage.

It was with these considerations before him, and with a desire to make ample provision for the future, that the writer recommended the Local Board to acquire by purchase 30 acres of land, of which 27 acres might be used for the disposal of the sewage, which, in dry weather, he considered, might amount, with the subsoil water, to 175,000 gallons, and be augmented by increased population to 350,000 gallons per day, at the end of 30 years; in wet weather, the writer considered that the outflow might fairly be taken at 500,000 gallons per day. Of the

27 acres, he proposed that 9 acres should be devoted to Intermittent Filtration, and the rest to Surface Irrigation. The Local Board rejected this advice, and determined not to prepare 30 acres, but to restrict the quantity to be utilised to certain lands bounded by the river, containing 22 acres, of which a portion which could not be reached by gravitation formed a part, leaving only about 19 acres available for use. And it is more than probable that if the expectations formed at the outset as to quantity of sewage and character of soil could have been realised, this extent of land would have sufficed for the cleansing of the sewage of Hitchin for thirty years to come.

The 22 acres of land cost, with legal expenses, nearly £4,000.

It turned out, however, when the time came for executing the works, that only two-thirds of the length of the main outfall sewer could be replaced by another sewer independent of the river, without derangements of a very serious character. It was therefore determined not to fulfil this part of the undertaking, and the water which found its way from the river into the remaining third of the length still remains to dilute the sewage discharged on to the land.

Dry weather outflow augment.

The constant addition to the "sewage proper" from this source and from the subsoil in which the internal sewers of the town are laid amounts to more than the whole of the water supply of the town, and, therefore, to more than the "sewage proper" itself. The water abstracted from the river and turned into the sewers by the Fellmonger, under his legal rights, serves also to augment the outflow already increased by the subsoil water.

Actual outflow from sewers.

The quantity of sewage, diluted with these subsoil and foreign waters, which actually finds its way on to the sewaged land in dry weather varies in some measure according to the season, but it is never less than 400,000 gallons in the 24 hours, which is 50,000 gallons more than the writer anticipated when he recommended 30 acres as the quantity of land to be provided for the disposal of the sewage 30 *years hence.*

When the removal of the surface waters from the sewers came to be considered by the Board, it was found too that the work of separation was so difficult that it could only be partially effected. The result has been that so much tributary surface still remains to throw off the rainfall into the sewers that if only a quarter of an inch falls on the town, the outflow from the sewers is suddenly increased to an amount quite equal to that of the sewage proper, and such is the rapidity with which this extra discharge is delivered to the land, owing to the great fall

the sewers possess, that no arrangement for distribution can meet the difficulty.

Difficulties to be contended against.

While these facts were being discovered and the decision of the Board to reduce the area of land from 30 acres to 22 acres was being acted upon, it was found that the extent of boggy peat, a soil which repeals, in a measure, percolation, formed a much larger proportion of the land than previous examinations had led the writer to anticipate.

Thus, whilst the quantity of diluted sewage to be cleansed amounted to more than it was expected would be the case 30 years hence, and it was found that the larger part of the land consisted of soil which could not be termed "suitably constituted," the total area utilised was very considerably reduced by the decision of the Board. At no very distant time, however, it may be assumed that the Board, following the example of Kendal, will extend the sewaged land from the 22 acres to the 30 acres originally recommended, and so bring into use eight acres of land of a more suitable character, when the difficulties which have now to be contended against will be completely overcome.

Outlay.

The total expenditure on the land, with screening tanks, roads, and fencing, as well as the construction of a very expensive outfall underdrain to take the effluent water under the river to the tail of a mill below, has been £2,300, including all incidental expenses. For this sum nearly the whole of the land has been laid out for Intermittent Filtration, instead of nine acres only, as originally intended.

The land is let to the writer at £55 per annum, and the charge on the ratepayers is 3*d.* in the pound to repay cost of land and its preparation.*

Effluent analysed.

In spite of the difficulties that have been experienced in this case, owing to the excessive dilution of sewage and the existence of so large a proportion of peat in the land utilised, the effluent from the underdrains having been analysed by several chemists of eminence, has

* Being a resident in the neighbourhood of Hitchin the writer holds this small farm with a view of testing the *capabilities of a peaty soil* to cleanse sewage when subjected to the extreme drawbacks of great dilution of sewage (by both subsoil and surface waters) and a reduced area of land. The result in relation to the cleansing of the sewage is given in the text. The capability of a soil consisting chiefly of a boggy peat to yield heavy crops of roots and vegetables while acting as a filter is proved by the facts that the gross returns amounted in 1879 to £325 9*s.* 10*d.*, and in 1880 are estimated at £420. One of the disadvantages attending the use of peat is that it must be cultivated by spade husbandry, and that the tenant's expenditure is thereby increased. (*December*, 1880.)

been declared by them to be well within the standard suggested by the Rivers Pollution Commissioners. Professor Attfield gave the following results :—

"ANALYSIS of Effluent Water taken, April 1st, from Underdrain from Soil which is principally Bog Peat :— 1878.

LONDON, *April 4th*, 1878.

One gallon contains the following number of grains and decimal parts of a grain of the respective substances :—

Total solid matter, dried at 212° F.	40·
Ammoniacal matter yielding 10 per cent. of nitrogen	0·45
Albumenoid organic matter yielding 10 per cent. of nitrogen	0·03
Nitrites	Traces.
Nitrates containing 17 per cent. of nitrogen ...	3·4
Chlorides, containing 60 per cent. of chlorine	4·2

"(Signed) JOHN ATTFIELD."

Professor Wanklyn gave the following results of an analysis made by him of a sample taken without knowledge of the writer by the Surveyor of the Croydon Local Board. The copy here printed was politely supplied by order of the Croydon Board.

"ANALYTICAL REPORT.

Laboratory, 7, Westminster Chambers, S.W. 1879.

		Grains per Gallon		Parts per Million	
		Solids.	Chlorine.	Free Ammonia.	Albumenoid Ammonia.
1879 8th Oct.	Sample of water, 'Effluent water from the Sewage Farm at Hitchin,' sent by the Croydon Local Board	36·3	3·3	5·00	1·00

"This is *not* drinking water; but it may be discharged into a stream.

"(Signed) J. ALFRED WANKLIN."

Having in the preceding Eight instances of Sewage Disposal shown what has been done with "suitably constituted soils" and with those of a less inviting character, the following cases are added to show what has been done in smaller cases of varying character.

9. OAKHAM, RUTLAND.

Oakham, 3,000.

Oakham is the county town of Rutland, and has a population of 3,000. The town—which has been recently sewered by Mr. C. W. Whittaker, C.E., of Great George Street, Westminster, is for the most part, together with the land surrounding it, the property of Mr. G. H. Finch, of Burley-on-the-Hill, M.P. for the county. In consideration of the improvement the sewerage of the town would be to his estate, Mr. Finch undertook at his own expense to dispose of the sewage (though much diluted by subsoil water) on his own land.

Mode of disposal.

Under the advice of the writer (given in 1878), the method of disposal adopted was Intermittent Filtration through land, three acres in extent, with Surface Irrigation over some adjacent land. The site selected is on the marlstone of the lias formation. The rock of this stratum here comes to the surface, and the cost of forming the land, which has a rapid slope into level terraces, was, therefore, very considerable.

Cost and current outlay.

Mr. Finch himself directs the mode of treating and cropping these filtration beds, and employs to work them one man, whose wages amount to £44 4*s.* per annum. It has been found, after two years' use, that the whole of the sewage of Oakham may be cleansed on the three acres of filtration ground, though it has been found advantageous to apply some of the sewage in irrigating about five roods of land immediately below the beds.

Return.

This year the money return from 2½ acres of mangold and from half an acre of cabbages grown on the filtration areas, and the five roods of Rye Grass, has been £85 5*s.*, leaving a balance, after payment of the water-man's wages (£44 4*s.*), of £41 1*s.* This pays Mr. Finch his rent for the land and the current outlay in seeds, &c., as well as about 2½ per cent. on his expenditure in preparation. If, at a future time, he desires to extend the use of the sewage on his estate, he has it in his power to do so at very little cost.

General Result.

Mr. Finch, writing to the author (December 1st, 1880), says:—

"The Oakham Beds work capitally, though they have occasionally been overburdened with Storm Water during some of the heavy rains

this summer. The analysis of the effluent last year was everything that could be desired. The great point I had in view when I undertook the construction of the Oakham Sewage Beds was the purification of the sewage, and this object I seem thoroughly to have obtained."

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10. EARLSDON } WARWICKSHIRE.
11. RADFORD }

Populations.

These two cases, Earlsdon and Radford, are bracketed together because they are both *Suburban Villages* in the near neighbourhood of Coventry. They contain present populations of 1,000 and 600 respectively. The sewage is collected in each instance in a "Self-acting Sewage Regulator" tank, discharging, when full, by means, in the one case of a "syphon" and in the other of a "float outlet." The "Self-acting Sewage Regulator" is an invention to discharge, automatically, the quantity of sewage or other liquid which may be applied to land, either for the purpose of utilization or purification. One of the most prominent difficulties which presents itself in the utilization of sewage, is the very different quantity which is discharged from sewers at different times. In many towns and villages the flow will be diminished, at certain periods, to a mere dribble; while at other times there will be a copious discharge. Hence, as it is essential to economy in sewage farming that the crops should receive only that quantity of sewage which will produce the most fruitful growth, and as it is equally essential to success in Intermittent Filtration that the soil used to purify the sewage should receive only the quantity which it is capable of purifying, it is very desirable, as already pointed out, to have a means of regulating the quantity of sewage to be dealt with. "The Self-acting Sewage Regulator" performs this service in the most simple and perfect manner, during the night, as well as during the day, and without any supervision. The sewage is made to flow into a tank of such capacity that when the liquid rises to a given level, the tank holds the precise quantity it is desired to deliver to a certain area of land at one time. This tank is provided with a syphon, or other self-acting outlet, which is brought into action as soon as the liquid rises to the given level. When this is reached, the liquid flows out of the tank ("automatically"), and continues flowing until the level of the liquid in the tank has fallen to its lowest limit. The sewage flowing into the tank then fills it again,—

"Regulator" used.

slowly or quickly, according to the rate of influx,—and, as soon as it is full, the automatic discharge will be repeated, and the liquid can be applied either to the same area of land, or to another, as desired. The coarser matters floating in the sewage are intercepted in a separate chamber, called "the intercepting chamber," the finer particles being carried forward with the liquid through the strainer into the tank. If it be desired to effect a precipitation of these finer particles, the space in the Meter-tank below the mouth of the outlet is increased in depth, so as to form a receptacle for any amount of deposit which it may be determined to precipitate. In such case the space *above* the mouth of the outlet will be occupied by clarified liquid, to be discharged on to land automatically as already described, while the space *below* will serve as a receptacle for the deposit, means, in some cases, being provided by a duplicate tank for draining off the liquid, so as to allow of the consolidation of the deposit for removal. These Regulator Tanks are duplicated or not, according to the quantity of sewage under treatment and the use to which the precipitated matter is to be applied. Where the quantity of deposit is trifling, it can be flushed out periodically without consolidation, and applied directly to the land.

Earlsdon, population 1,000.

The quantity of land purchased by the Sanitary Authority for Earlsdon, which consists of clay of the New Red Sandstone intermixed with sand and gravel, was $3\frac{1}{2}$ acres, of which rather less than 2 acres were prepared for Intermittent Filtration, while the rest remains in an unprepared condition for sewage appropriation as required. The two acres have been in use for sewage cleansing since 1875, discharging an effluent of a superior character during the whole of that time. The whole of the land ($3\frac{1}{2}$ acres) is let for £10 a year, and although such a return in itself is insignificant the advantage is really considerable, inasmuch as the tenant relieves the Local Authority from all current outlay as well as all trouble in the matter.

Acreage used.

Radford, population 600.

In the case of Radford, Intermittent Filtration on a less area was adopted by the same Authority in 1879, after the success at Earlsdon had been assured. Here $2\frac{1}{2}$ acres were purchased, while $1\frac{3}{4}$ acres were utilised for filtration. The land ($2\frac{1}{2}$ acres) is now let for £7 10*s.* a-year, the tenant taking upon himself the distribution of the sewage.

In both instances the land utilised is not far from habitations, yet no objection has been raised on the ground of nuisance.

12. CONVALESCENT HOSPITAL, WALTON, SURREY.

Convalescent Hospital, Esher.

This case is given as one showing what may be done unobjectionably with sewage in the case of *Public Institutions and Isolated Dwellings*. Here the land devoted to the cleansing of the sewage daily discharged from the hospital forms the vegetable garden attached to it. The number of inmates varies from 250 to 400 persons. The disposal works were executed in 1869.

The tank in which the sewage is collected is discharged by means of a sluice which the attendant raises in the evening or early morning once in the 24 hours. The area of land devoted to the purpose of cleansing is rather more than an acre, and although it immediately adjoins the hospital and has been in use for more than 10 years, no nuisance has at any time been experienced. It will be observed that this instance of sewage treaament by filtration was executed *before* the publication of the Report of the Rivers Pollution Commissioners, in which "intermittent downward filtration" was first suggested, and it is somewhat remarkable that the effluent was analysed for the Managing Committee of the Hospital by an eminent chemist and declared to be excellent "potable water," which is in some measure to be explained by the fact that the effluent when discharged is diluted by the subsoil water drained out of the land.

Standing Rules to be observed when adopting Intermittent Filtration.

Having selected from works designed and executed by the writer's firm, a dozen cases of Intermittent Filtration, varying in size and character, as illustrations of what may be done in different localities, it may be well to state, in the order of their importance, the governing rules essential to the *successful* (*i.e.*, *profitable*) *disposal of sewage* when recourse is had to land as the cleansing medium.

1. Foreign waters—subsoil water, surface water, and liquid trade refuse—should be, as far as practicable, excluded from the sewers of

all districts, inasmuch as it matters not what the precise treatment of the sewage be—irrigation or filtration in combination or otherwise,—it is certain that if the sewage proper be diluted to such an extent that the *modus operandi* is at times deranged, failure or injury results.

2. The preparation and formation of land to receive sewage should be effected *with precision*, and not in the careless way in which it has been suggested sewage farms may be laid out. Irregular surfaces and steep slopes should be avoided even more carefully than clay soils, for all liquids will run down sloping surfaces and collect in the lowest places, to the injury of crops and the creation of nuisance, and the more sewage is diluted with foreign waters, the greater will be these evils. There is no economy in carelessly executed land-preparations, and it is greatly to be regretted that such views have been inculcated.

3. Intermittency of application and regulation of quantity should take the place of the haphazard distribution which prevails on most sewage farms, for it is the want of these *desiderata* which brings discredit to the engineer and loss to the farmer. With sewage *intermittently* distributed in quantities apportioned to the extent of surface to which it is applied, the best results are obtained. Intermittency of application is positively essential to a continued good effluent. Where an inferior effluent from underdrains is found it is invariably due to *constant* filtration through the same land.

When Intermittent Filtration areas are properly laid out on a perfect level, and intersected by furrows dug at different depths, the liquid sewage will convey to the land, where it is most wanted, those floating solid particles which are not arrested by ordinary screening. The furrows being designedly dug at different depths and in selected positions, the deeper ones become the receptacles of the solid ingredients called "sludge," which having passed through the screens deposits itself in them, while those at less depth serve to distribute the *liquid* evenly through the soil. It will be found that by resting the sewaged areas, one after another, as soon as this *wet* sludge has accumulated in the furrows, it will there solidify and dry, and may then be removed and spread upon the land without any difficulty whatever. Being afterwards dug in it mixes with the soil and renders it *more percolative than before*, and thus all necessity for separating the solid from the liquid portion of sewage is avoided,—except possibly in the case of certain trade refuse which may require special treatment.

It is quite a mistake to suppose that land may be made too rich by sewage where plant growth is regarded as one means of rendering the soil a purifier.

5. Where Intermittent Filtration areas form part of an irrigation farm a sufficient proportion of the areas should be always ready to receive the sewage when it cannot be beneficially applied to the remainder, or to receive so much of it as may be in excess of what the remainder will absorb with advantage.

6. The underdrainage of both Filtration areas and surface irrigated land should be laid out as carefully as practical science will suggest so as to avoid drawing the liquid sewage down from the surface to the drain without passing through the undisturbed ground on each side of it.

7. Means should be taken in connection with the screening to intercept road detritus as far as possible, as it will be apt to fill up the furrows quickly.

To arrive at the actual cost of *disposing of Town Sewage*, by recourse to land, or indeed by any means, it is necessary that the calculations should be quite free of any outlay connected with the sewerage of the district or with the lifting or delivery of the sewage to the disposal works.

Pumping should be included in the cost of the Sewerage, and not in that of Sewage disposal.

The delivery of the sewage in some cases may involve pumping, whilst in others the sewage may flow to the works by direct gravitation. In the former instance, the cost of pumping forms a part of the cost of the system of sewerage, and not of the disposal of the sewage.

Land Treatment compared with Chemical precipitation.

With the foregoing particulars recorded, it may answer a useful purpose if the cost of the treatment by land is compared with that of chemical precipitation in tanks, taking for the purpose those instances of the latter mode of disposal as may be fairly put forth as examples of well received processes.

I will compare Aylesbury, where the Native Guano Company have relieved the Local Authority of treating the sewage of their district, and are exhibiting the ABC process (alum, blood, clay, and charcoal) in the best form to recommend its adoption, with Abingdon, the mode of dis-

Aylesbury compared with Abingdon.

Hertford compared with Halstead.

posing of the sewage of which has been described in these pages; and I will further compare Hertford,—where the Rivers Purification Company (sulphate of alumina) occupy the same position in relation to the Sanitary Authority of that borough as the Native Guano Company do with the Local Board of Aylesbury,—with Halstead. The following results are arrived at:—

	Aylesbury.	Abingdon.	Hertford.	Halstead.
Population...	7,200	6,000	7,250	6,000
	£	£	£	£
Cost of tank arrangements	7,265	—	3,300	—
Cost of land and preparation	—	10,640	—	3,500
Interest on outlay... ...	363	532	165	175
Add payment of subsidy to the Companies after deducting rent of premises	200	—	600	—
Total annual charge ...	563	532	765	175
Deduct rent or income from land	—	225	—	50
Amount chargeable on the rates of the districts ...	563	307	765	125

From these figures it will be seen that in the two towns, Aylesbury and Hertford, where tank arrangements are used, the annual charge on the ratepayers is severally 1*s.* 7*d.* and 2*s.* 1¼*d.* per head, while in the two towns, Abingdon and Halstead, where land treatment has been adopted, the charge on the ratepayers is severally 1*s.* 0¼*d.* and 5*d.* per head of the populations.

The comparison of Aylesbury with Abingdon is one that cannot be impeached on any ground of difference in conditions, though it is possible that the outlay of £7,265 expended by the Local Board in tank arrangements is in excess of what the Native Guano Company would themselves have laid out for the prosecution of their own process; but against this proposition there stands the liability of the Aylesbury authority to repay the Native Guano Company any sum that they may have expended for their own purposes by valuation at the end of their present lease. It may be assumed, therefore, that so far as outlay in works or land goes, the relative figures represent

fairly the facts in each case. On other grounds the cases demand consideration. Should anything occur to lead to an abandonment of the present works at Aylesbury, it will be found that the property belonging to the authority will have no renting value, but will consist of the materials of which the tanks and works are made with the comparatively small area of land upon which they were constructed, for which but little money would be given if sold, whereas at Abingdon, if the present mode of disposal were given up, the borough would possess a property consisting of Cottage, Homestead, and 48 acres of land which would at any time let for £170 a year, and if sold would realise £5,000. Moreover the present charge on the ratepayers at Aylesbury is 5¼*d.* in the pound, whereas that at Abingdon is 4½*d.*, in respect of the respective outlay for sewage cleansing.

With regard to Hertford and Halstead the same observations will apply with a wider difference between the two. At Hertford the charge on the ratepayers (irrespective of the contribution of the New River Company) is 7¼*d.* in the pound, whereas the charge at Halstead hardly reaches as much as 3*d.* in the pound. It is true that at Hertford the sewage is diluted with subsoil water to an extraordinary extent, whereas at Halstead there is an absence of any sensible dilution, showing distinctly the effect of an influx of foreign water and the necessity of water-tight sewers, if economy is to be considered. It must not be supposed that the quantity of liquid regulates the quantity of land required for purification if the land is of a "suitably constituted" character. If reference is made to the descriptions given of the operations at Merthyr, Kendal, Abingdon, and Malvern, it will be observed that the quantity of water absorbed per acre day after day has exceeded 200,000 gallons. Wherever detention on the surface takes place it is found to be due to the sludge deposited *while wet*, which forms a puddle to resist infiltration. This resistance is very trifling in suitably constituted soils.

At Hertford the sewage of 7,250 people is daily mixed with upwards of 1,000,000 gallons of subsoil water. Still, if we have regard to every day's experience in Intermittent Filtration, we shall be assured that 20 acres of the free soil surrounding Hertford would be amply sufficient for the perfect and constant purification of the sewage of 7,250 persons though it may be diluted by mixture with more than a million gallons of subsoil water.

Should exception be taken to these comparisons it would be well for

the reader to examine the facts relating to the disposal of the sewage of Birmingham. There one-third of the sewage is cleansed by treatment on land, and two-thirds by chemical precipitation. The former showed in 1878 *a balance of annual receipts over annual expenditure* (exclusive of rent of the purchased land) *of* £1,064 18*s.* 7*d.*, whilst *the cost of the latter process* (the chemical treatment) *was* £11,987 15*s.* 3*d.* (See *Journal of the Royal Agricultural Society of England. Second Series, vol.* xvi, *part* 1.)

SEWAGE FARMING.

EXPERIENCES AND RESULTS.

It is not many years since several of the leading chemists in Europe held out to the followers of the twin arts of agriculture and horticulture the prospect of enormous returns from the use of human refuse in their occupations; the farmer and the gardener, in fact, were alike told that though it might call forth a new class of cultivators as "sewage farmers," they would each have it in their power by the use of excretal matter to increase the production of food so rapidly and so largely that it was difficult to limit the profit they severally would gain. The benefit that such increased production would be to the world at large was at the same time pointed out with equal force.

Boussingault showed that an adult gives off in his excrements as much as 16 lbs. of nitrogen yearly, which is a quantity sufficient to yield 800 lbs. of wheat and 900 lbs. of barley, while Baron Von Liebig went so far as to say that each unit of the population can, on an average, supply with nitrogen absorbed from the atmosphere, sufficient manurial matter to raise from an acre of ground "the richest possible crop each year;"—and no doubt of the accuracy of these statements has ever been recorded on sufficient data to cause disbelief.

Chemists' value of sewage.

Somewhat more appositely to the utilization of sewage, Messrs. Lawes and Gilbert, the eminent chemists, whose efforts in the cause of agriculture are so highly appreciated in this country, have shown that 8*s.* 4*d.* represents the intrinsic value of sewage per head of the inhabitants of water-closet towns, whilst other equally well known authorities on the subject have arrived at figures, some above and some under this estimate. The consulting chemist of the Royal Agricultural

Society of England, Dr Voelcker, by taking the value of ammonia at 9*d.* per lb., and that of phosphates at 2*d.* per lb., has declared the total value of human excreta per head to be 9*s.* per annum.

These estimated values were doubtless well based on true analyses, and are abstractedly correct, but it has been found in the practical utilization of sewage that when the fertilising elements are diluted with 61 tons of water per annum (the average quantity contributed by each individual to the outflow from towns, *i.e.*—25 gallons of sewage proper + 50 per cent. of subsoil water × by 365 (days) ÷ by 224 gallons = 61 tons—) not only does the productive value shrink to a very small amount, but that such a bulk of diluted sewage, if compulsorily applied (which too often means inappropriately), actually causes mischief rather than benefit. Instead of 1⅔*d.* being the value, as it would appear to be by dividing 8*s.* 4*d.*, the chemist's value of sewage per head, by 61, the number of tons which it has been already explained represents the diluted quantity of liquid per head to be dealt with, it is actually reduced by attendant drawbacks to the present mode of application to much less than *one farthing* per ton.

Even with such a greatly diminished value as a farthing a ton, however, the country has a valuable property which it is our duty to preserve. Yet such a difference between estimated chemical value and actual realisable value is a satire upon our practical character which we should do our best to remove, for it is certain that 1⅔*d.* is as much too high as a farthing per ton is too little. To appreciate the quantity of sewage at command, and to arrive at the true productive value of the property at stake, it should be remembered that in England alone there are 13 towns—excluding the Metropolis—which have populations above 100,000, 19 between 100,000 and 50,000, 178 between 50,000 and 10,000, and 549 between 10,000 and 2,000; and that if only half of these towns, with an aggregate population of 5,000,000, ultimately determine to utilise their liquid refuse by application to land, the annual quantity at disposal will be 305,000,000 tons. This quantity at a farthing a ton will amount to upwards of £300,000 a-year which may be taken to represent the annual value of upwards of 200,000 acres of unsewaged land, or that of the *farmed land* of Huntingdonshire.

Setting on one side the chemist's estimate of 1⅔*d.* per ton, the liquid sewage of 100 persons seems to have been adopted by common consent as the average quantity that may be advantageously applied each year to an acre of land. Upon what data this conclusion has been come to

it is difficult to say, for the sewage of 100 persons would in quantity amount to 6,100 tons, which at the chemist's value would be worth upwards of £25.

It can be readily understood that no tenant farmer *if obliged to take* 6,100 *tons per acre*, which is equivalent to a superincumbent depth of 5 feet, or 2½ times the average annual rainfall, would give even a farthing a ton for it,—which would amount to £6 7*s.* 1*d.* per acre,—though he would gladly give a price calculated after the full rate of 1⅛*d.* per ton if he could have what he wanted just at such times as he wanted it.

Depth of a single dressing.

No single dressing of liquid, to be productive of benefit, should exceed an inch in depth, and directly the quantity applied to an acre of land exceeds that depth, which is equal to 100 tons, the surplus is positive waste, which should not be paid for. All land laid out for *irrigation* has sloping surfaces which cause the liquid to run down to the lower portions of the surface and to rest there in slacks and hollows until it is absorbed or evaporated, doing mischief in the meantime. The farmer paying rent for land with sewage soon finds this out. He knows that he cannot profitably apply more than 20,000 gallons at a dressing except to fallows, *bare of vegetation, which no sewage farmer ought to* have in the growing seasons.

Experience, in fact, goes to prove that sewage, let its intrinsic value be what it may, directly it is delivered to land by way of Surface Irrigation, without that systematic arrangement which will secure regularity of distribution in the quantities that will be beneficial, ceases to be of any value at all. Without system the distribution of sewage on the surface becomes what has been termed "intensive irrigation," or in other words the "getting rid of the sewage in the quickest way," with an indefinite chance of turning its fertilising ingredients to some account at the same time, when harm rather than good is frequently done.

If we turn to the best examples of sewage farming we shall find these statements exemplified in different degrees.

Lodge Farm, Barking.

The figures very accurately given by Mr. Morgan, when managing the Barking Farm for the Essex Reclamation Company in the last year in which he published a Return, showed that he expended as much as 21,488 tons of sewage per acre on one crop of Italian rye grass, which at 1*d.* a ton, the *least* amount at which sewage has been valued by chemists, would amount to £89 10*s.* 8*d.*, and at a farthing a ton to £22 7*s.* 8*d.*, which every practical farmer or gardener knows to be unreasonable, and quite inconsistent with profit, because a very large

proportion of the liquid must necessarily be unproductive of any return whatever.

Leamington. Turning to what has been so patriotically done by the Earl of Warwick on the Heathcote Farm and on adjacent farms on the same estate (the largest illustration of sewage utilization in England) upon which the sewage of Leamington is applied, we find that whilst his lordship pays the Corporation less than one-third of a farthing a ton, it has been retailed to his tenants at a much less price, an arrangement which is not surprising, seeing that the sewage was distributed among them (in 1878) after the rate of 11,583 tons per acre irrigated.

Doncaster. On the Doncaster Farm, which has the advantage of excellent management, as much as 17,505 tons per acre was applied in the same year (1878) to rye grass, 6,455 tons to mangolds, and 4,505 tons to permanent pasture, which at a farthing a ton would amount to upwards of £18 4*s.* 8¼*d.*, £6 14*s.* 5¾*d.*, and £4 13*s.* 10*d.* respectively. These figures are not quoted with the intention of proving that the sewage was not worth the sums set forth;—they are given to show that so long as irrigation is conducted in the manner now followed, an estimate of even one farthing a ton cannot be justified, and if sewage is not worth a farthing a ton it may be well asked, how can agriculture benefit by its use? In fact these figures prove incontrovertibly the absurdity of placing any value at all on sewage distributed in irregular quantities, and show distinctly the necessity of a different treatment if the nation is to be advantaged in any sensible degree.

There is no disguising the fact that the constantly repeated attempts to reconcile, in one operation, the two objects of *cleansing* and *profitably applying* sewage have brought the mind of the country into such a state of confusion and disbelief in the power of obtaining any profit from sewage utilization, that it will be almost impossible to re-establish a different view. This is greatly due to the fact that up to this time some of our most able men have been using the great influence of their voice and pen in advocating the application of sewage to "ordinary farming," with plough-made furrows and such like expedients, and have declared—

"That sewage farming should not be dealt with as a distinct branch of husbandry, but that in order to make it successful it must be engrafted on ordinary agriculture!"

It is the object of the present treatise to show that if our fields are really to benefit by the liquid refuse of our towns we ought to do just the

reverse, assuming that by *engrafting sewage farming on ordinary agriculture* it is meant that the liquid should continue to be distributed, as at Leamington and Doncaster,* in irregular quantities at times when it is not wanted. In neither of these cases has it been proved that a tenant farmer could afford to pay one farthing a ton for the sewage applied. All experiences tend to prove that the obligation to "get rid" of a large quantity of sewage under all circumstances and conditions, at night as well as day, on Sundays as well as week days, on cropped lands as well as fallows, and at all stages of growth, from seed-time to harvest, puts it beyond the reach of man to gain any real profit from it.

Fortunately for the ratepayers of urban districts the last 10 years have conclusively shown, as I hope the instances given in this treatise will further confirm, that a comparatively small extent of land deeply drained and properly prepared, varying in extent, as already explained, from 1 acre to 1,000 to 1 acre to 250 people, according to the nature of the soil, will, if treated by Intermittent Filtration, under good management, suffice for sewage purification *per se*, and allow of the growth of heavy crops of grass, roots or vegetables at the same time.

Fortunately, too, for agriculture, it has been made equally clear that it is quite practicable to prepare and use as a safety-valve, a proportion of any sized farm for Intermittent Filtration whilst delivering to the remainder of the farm only so much sewage as the occupier would deem desirable, so that in fact, if he requires a large quantity as a dressing for Rye Grass or other artificial grasses, or a comparatively small quantity for roots or cabbages, he can have just what he wants and no more.

It can only be by some such "*safety-valve arrangement*" that the true value of sewage can be realised; not that a sewage farmer may ever be able to pay 1⅝*d.* per ton for what may be delivered to him, though, as already stated, it is certain that he will be better able to pay even that price for what he actually requires than a farthing per ton when the liquid is crowded upon him in such quantities and at such times as he cannot utilise it. In asserting this, the writer speaks from a lengthened experience, first as an ordinary farmer, and afterwards as a sewage farmer.

* The experience at Cheltenham does not help to solve this question. There the sewage is cleansed by surface irrigation over land which is let by tender annually subject to the distribution of the sewage as the Sanitary Authority thinks well to apply it for its own purpose. The return for the *sewage* after the rent of the land is paid is reckoned to be 1½*d.* per head per annum of the population.

As sewage farming is now conducted, with irregular supplies of liquid and surfaces ill-formed,—under the supposition that it is economical to adopt the rough-and-ready style of preparation and distribution amidst obligations and drawbacks of the formidable character already mentioned —it is found that the greater the width of land laid out to receive sewage by way of irrigation *the greater is the loss to those who pay for the sewage used*, showing distinctly that from an agricultural point of view the present mode of irrigation with sewage is the reverse of what it should be in the interests of the nation. In fact at the present time *there are various sewage farms to be hired at rents less in amount than would be given for the same land without sewage.* Can anything more conclusively prove that the mode of distributing the sewage is at fault? With the intrinsic value of sewage, 1⅝*d.* per ton, it could hardly have been supposed that we should be obliged to acknowledge this fact.

Among the instances given in the preceding examples that of Great Malvern may best serve to show what may be done in the way of combination of Intermittent Filtration with Surface Irrigation in order to obtain from sewage a satisfactory return. At Malvern the daily dry weather overflow, amounting to 350,000 gallons, may be concentrated on any one of the 11 areas devoted to Intermittent Filtration, consisting of a little more than an acre, and the 35 remaining acres forming the cultivation of the farm relieved of sewage altogether. By judicious use of the filtration areas any part of the farm may receive that quantity of sewage for fertilising or watering as may best conduce to the largest money return, and in this case provision is made for sewaging adjacent lands whenever it may be found profitable to do so. Special arrangements, too, are made for dealing satisfactorily with surplus (storm) water.

Qualifications of a sewage farmer.

The same experiences that have made it manifest that to secure any chance of profit in sewage farming, the liquid must be distributed in regular quantities and at proper times, has also satisfied all practical men that the early expectations entertained as to the general applicability of sewage to ordinary farm crops cannot be realised and that a sewage farmer to qualify himself for success must serve a special apprenticeship to the occupation. Moreover, it has been made clear that an ordinary farmer is no better qualified to deal with sewage without such apprenticeship than a gardener, for not only is it necessary to know what grasses and vegetables can be best treated by sewage and to regulate the frequency of application and the quantity of liquid to gain the best

return, but it is absolutely essential that he should be able to effect the best and readiest sale of his crops when fit for market and so to conduct his operations with reference to the demands of local markets and of such other markets as he can best reach, as will conduce to the growth of only such crops as he can most readily sell. By this means he will reduce to a minimum the losses incidental to all food production. for it is quite certain that in the long run the man *who sells the most at the right moment, and who aims at converting into milk or meat what he cannot sell,* is the person who will make the most money. To do this it is absolutely requisite that every sewage farm should have upon it sufficient buildings to house a proper number of milch cows and pigs to consume a portion of each season's produce. Buildings essential.

It is essential, in fact, that a tenant of a sewage farm should combine in his own capabilities the practical qualities of a farmer, a gardener, and a market salesman, which will induce him to avoid all treatment of a *dilettante* character and lead him to embrace in his management the growth of such crops only as will keep him most favourably before the markets he serves. Many of the ordinary farm crops are injured by the application of sewage to them. Cereal and pulse crops, instead of being benefited by its *direct* application to them while in growth, are damaged by the increase of straw at the expense of the grain;—potatoes and turnips are also injuriously affected in a like manner. Kohl Rabi seems to do better.

It is equally true that heavy crops of both grass and vegetables may be produced without the capability of selling them. Not many years back the possibility of growing Italian rye grass without the certainty of sale or conversion was ridiculed as an absurdity, yet the last few years have satisfied all sewage farmers that it is not only possible to grow more rye grass than can be sold but that if retained for conversion either into milk or into hay, it is very problematical whether in one way or another, some loss does not attend the operation. Still there are crops which when advantageously selected cannot fail to yield a profit if the liquid is rightly applied. Rye grass.

Up to a limited extent rye grass of all productions is that which best responds to the use of sewage unless it be prickly comfrey, which is an excellent forage plant for horses and may be profitably consumed with rye grass by cows. Moreover, it would appear that it can never be overdosed with sewage.

All the cabbage tribe are also greedy of sewage and although in Cabbages.

certain seasons it is very easy to have too many for market, there is no doubt that in the long run they pay well, particularly if pigs are kept on the farm to consume any unsold surplus. The Enfield Market, Colewort, and Ox-heart cabbages, if they stand through the frost of winter, realise a good return in early summer, while savoys and drumheads—which latter, though more frequently treated as the food of cattle, sell remarkably well to the inhabitants of the manufacturing and mining districts,—are generally very saleable in late autumn and winter. Under good management the two crops of cabbages of summer and winter are grown in the same year on the same land,—that is, the summer cabbages planted in October are cut in May or June, when the land is again prepared for savoy and drumhead cabbages, which may be planted in sufficient time to be cut the following winter and the ground cleared in time for a succession of roots.

Mangolds.

But on the whole, mangolds (long red, tankard and globe) form the best crop for the sewage farmer if the selected seed is good and it is carefully sown, and advantage is taken of a command of sewage for timely watering to secure a plant. The weight of crop will always vary with the temperature of the summer, but under any circumstances the crop from a sewage farm will, compared with that from an ordinary farm, surpass it in both weight and quality. It would appear that if the land is *well drained* so that the liquid readily percolates, mangolds of all roots will flourish best with a superabundance of liquid. This year (1880) the writer has grown on 13 acres of land, forming part of the filtration areas at Hitchin, 400 tons of these roots, which is equal to 31 tons to an acre. These 13 acres have received, perhaps twice a week, 100,000 gallons per acre. These mangolds were raised, carried from the peaty soil, and clamped ready for sale at a cost of £45, so that if they should sell in April or May at £1 a ton clear of carriage, they will realise £27 6*s.* an acre.

Carrots and parsnips.

Carrots and parsnips do equally well in a free sandy soil. At Forfar this year (1880) a price equal to £56 an acre was gained by the growth of carrots on the filtration areas. On inferior free soils, the Intermediate Red Carrots are best, but on naturally deep sandy loams the Altringham Reds yield the greater weight. White Carrots for cattle pay well in suitable soils, but with them and all other sorts of carrots—as well as with parsnips—no amount of sewage will make an unsuitable soil productive of heavy crops.

Sewage farmers as a rule should avoid the growth of crops which

have not been well tried. Much money is lost by experiments in *refined* vegetable gardening, such as the growth of Lettuces, Parsley, Vegetable Marrow, Sugar Beet, &c.

Probably onions, if the soil is compact and suits them, and good judgment is used in watering them, pay better than any other crop, but there are few places where this root will succeed. They are altogether unfit for the superabundant watering of filtration ground. Onions.

To a small extent rhubarb and celery may be advantageously grown. Rhubarb, Celery.

CONCLUSIONS.

This Treatise would fail in one of its purposes if it were brought to a close without an expression on the part of the Author, both as an Engineer and as a Farmer, of the conclusions to which he has been brought by the experiences of the last 10 years in relation to the different modes of sewage disposal now practised in this country, and the effect they have had in promoting the production of food for our rapidly increasing population.

The conclusions are—

First.—Excluding from consideration sea-board towns, the sewage of which it may be expedient on all grounds to discharge direct into the sea, the instances are few in which the liquid refuse discharged from human habitations may not be more economically cleansed by recourse to land than by any chemical precipitation.

Second.—That the exceptions are only those where land cannot be obtained.

Third.—That the more minute floating solid matters, generally called "sludge," which cannot be separated from the liquid by screens designed to arrest the larger solids, form no bar to the use of land as a purifier. Such ingredients when conveyed to land, where they are always wanted, instead of clogging it, help to make it more percolative and more productive than it would be if such materials were withheld.

Fourth.—That if, instead of leaving sewage when applied to land to flow where it will over irregular surfaces in the varying quantities in which it is usually discharged from towns, proper

steps were taken to deliver for Surface Irrigation only such quantities as are wanted by the cultivator by taking advantage of the power we always possess of cleansing any quantity of sewage by Intermittent Filtration through a small area of land, not only would Sanitary Authorities conform to the requirements of the law in relation to the purification of their sewage *with a less charge upon contributing ratepayers than is involved in any other treatment*, but Agriculture would secure a benefit in its profitable utilization at present withheld; and

Fifth.—That by adopting properly-devised Intermittent Filtration areas, which allow of no overflow from the surface into rivers, nor any discharge but from the underdrains (except in times of excessive rainfall, and then only by regulated "Storm Overflows"), the *constantly recurring evils* due to inattention on the part of those who have the care of the disposal works, are completely removed.

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